In re Patent Application of: Takayuki Oe et al.

Serial No. 09/930,183 Examiner: SHENG, TOM V

Filed: August 16, 2001 Group Art Unit: 2673

For: METHOD OF DRIVING DISPLAY DEVICE CAPABLE OF ACHIEVING DISPLAY OF IMAGES IN HIGHER PRECISION WITHOUT CHANGING CONVENTIONAL SPECIFICATIONS OF PANEL

TRANSLATOR'S DECLARATION

Honorable Commissioner of Patents & Trademarks
Washington, D.C. 20231

Sir:

I, Hiroo Seki, residing at c/o A. AOKI, ISHIDA & ASSOCIATES, Toranomon 37 Mori Bldg., 3-5-1, Toranomon Minato-ku, Tokyo 105-8423, Japan declare the following:

(1) That I know well both the Japanese and English languages;

(2) That I translated Japanese Patent Application No. 2000-360760, filed November 28, 2000, from the Japanese language to the English language;

(3) That the attached English translation is a true and correct translation of the aforesaid Japanese Patent Application No. 2000-360760 to the best of my knowledge and belief; and

(4) That all statements made of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements are made with the knowledge that willful false statements and the like are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001, and that such false statements may jeopardize the validity of the application or any patent issuing thereon.

January 5, 2005
Date

Hiroo Seki
Translator Hiroo Seki

2000-360760(J140)

[NAME OF DOCUMENT] APPLICATION FOR PATENT

[REFERENCE NUMBER] 0001273

[DATE FILED] November 28, 2000

[DESTINATION] To Commissioner, Patent Office

[INTERNATIONAL PATENT CLASSIFICATION] G09G 3/20

[TITLE OF THE INVENTION] METHOD OF DRIVING DISPLAY DEVICE

[NUMBER OF CLAIMS] 1

[INVENTOR]
[Address or Residence] c/o FUJITSU HITACHI PLASMA DISPLAY LIMITED, 2-1, Sakado 3-chome, Takatsu-ku, Kawasaki-shi, Kanagawa
[Name] Takayuki Ooe

[INVENTOR]
[Address or Residence] c/o FUJITSU HITACHI PLASMA DISPLAY LIMITED, 2-1, Sakado 3-chome, Takatsu-ku, Kawasaki-shi, Kanagawa
[Name] Toshio Ueda

[INVENTOR]
[Address or Residence] c/o FUJITSU HITACHI PLASMA DISPLAY LIMITED, 2-1, Sakado 3-chome, Takatsu-ku, Kawasaki-shi, Kanagawa
[Name] Kosaku Toda

[INVENTOR]
[Address or Residence] c/o FUJITSU HITACHI PLASMA DISPLAY LIMITED, 2-1, Sakado 3-chome, Takatsu-ku, Kawasaki-shi, Kanagawa
[Name] Kyoji Kariya

[INVENTOR]
[Address or Residence] 2-43-17, Izumi, Suginami-ku, Tokyo
[Name] Shigeo Mikoshiba

[INVENTOR]
[Address or Residence] 764-403, Chitose, Takatsu-ku, Kawasaki-shi, Kanagawa
[Name] Tomokazu Shiga

[INVENTOR]
[Address or Residence] 2-9-5, Kugenumamatsugaoka, Fujisawa-shi, Kanagawa
[Name] Makiko Yamada

[APPLICANT]
[Identification Number] 394023218
[Name of Applicant] Shigeo Mikoshiba

[APPLICANT]
[Identification Number] 599132708
[Name of Applicant] FUJITSU HITACHI PLASMA DISPLAY LIMITED

[PATENT ATTORNEY]
[Identification Number] 100108187
[Patent Attorney]
[Name of Patent Attorney] Junichi Yokoyama
[Phone Number] 044-754-3035

[INDICATION OF FEES TO BE PAID]
[Registration Number for Prepayment] 999999
[Amount of Fee] 21,000 yen

[LIST OF ARTICLES TO BE SUBMITTED]
[Name of Article] Specification 1
[Name of Article] Drawing 1
[Name of Article] Abstract 1
[NEED FOR PROOF] Yes

[NAME OF DOCUMENT] SPECIFICATION

[TITLE OF THE INVENTION] METHOD OF DRIVING DISPLAY DEVICE

[CLAIMS]

[CLAIM 1] A method of driving a display device that comprises a means for controlling the light emission of each pixel in the display device by using a plurality of subframes into which one frame period for forming an image is divided, and that displays an image moving at a given speed on a display screen, wherein the method assumes on a retina a particular pixel to be focused on the retina, and controls the light emission in each subframe so that the luminance of the pixel on the retina becomes substantially equal to the luminance of an input image.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Technical Field of the Invention]

The present invention relates to a technique for improving image quality and achieving a high-resolution image display in a display device, such as a plasma display panel (PDP), that reproduces grayscales by using a time-division display method.

[0002]

[Prior Art]

In PDPs, when a moving image is displayed, the edges of the displayed image appear blurred. This is due to the persistence of human vision when the eyes follow the moving image. Such disturbance occurs based on the same principle that causes the major problem of PDPs called the moving image false contour.

[0003]

To reduce the moving image false contour, various strategies have been proposed in the prior art, which include, for example, a method that reduces the number of grayscales while increasing the number of light-emitting blocks, and a technique such as superimposition aimed at reducing the amount of shift in the center of gravity of light emission.

[0004]

[Problems to be Solved by the Invention]

However, when the above techniques are used, the image edge blurring becomes more pronounced. Therefore, to produce a natural-looking video image for display, the moving image false contour must be reduced without reducing the number of grayscales.

[0005]

Furthermore, to achieve a higher-resolution panel, not only does it become necessary to increase the addressing speed, but sophisticated manufacturing techniques are also required. Accordingly, it is not easy to increase the resolution of PDPs at the present state of technology. Besides, increasing the resolution incurs a reduction in light emission efficiency because of reduced discharge cell size.

[0006]

The present invention aims to alleviate the problem of edge blurring and to achieve a high-resolution image display without changing existing panel specifications. This method of the invention will be called the virtual pixel method.

[0007]

[Means for Solving the Problems]

To solve the above problems, the present invention provides a method of driving a display device that comprises a means for controlling the light emission of each pixel in the display device by using a plurality of subframes into which one frame period for forming an image is divided, and that displays an image moving at a given speed on a display screen, wherein the method assumes on a retina a particular pixel to be focused on the retina, and controls the light emission in each subframe so that the luminance of the pixel on the retina becomes substantially equal to the luminance of an input image.

[0008]

According to the present invention, the moving image false contour can be reduced by making the image focused on the

retina match the input image. Furthermore, by utilizing the spreading of light emission in a moving image, the present invention achieves a higher resolution display than the input image resolution without increasing the resolution of the panel itself.

[0009]

[Embodiments of the Invention]

The present invention is applied to a display device that displays an image by dividing one frame period into a plurality of subframes having varying light emission periods.

[0010]

Figure 1 is an input image (pixels to be displayed) and their corresponding pixels assumed on the retina. The method of assuming pixels on the retina is described in detail, for example, in Japanese Unexamined Patent Publication No. 2000-105565, and therefore, will not be described here.

[0011]

In the case of a still image, the luminances of the input image pixels Q, R, S, and T directly represent the luminances of the pixels Q', R', S', and T' assumed on the retina, as shown in Figure 1. However, when the image moves to the left (moving speed V = -3[pixel/field]), the light emissions of the pixels Q', R', S', and T' leave loci on the retina as indicated by dashed lines in Figure 2, if nothing is done. These loci are utilized to make the luminances of the pixels assumed on the retina match those of the input image pixels. For example, in the case of the pixel S' assumed on the retina, if the loci (indicated by thick lines) lying within the width of S' as shown in Figure 2 are caused to illuminate, S' can be made to illuminate with the same luminance as that of the input image pixel. This is because the length of the locus of that pixel (the total length of the dashed line extending, from the left edge of S' at time = 0, obliquely downward to the right) coincides with the sum of the lengths of the thick line segments. As a result, since the position and luminance of the

pixel on the retina match those of the input image pixel, it follows that the moving image false contour is reduced. Here, if the luminance of the original image pixel S is that achieved by causing it to illuminate in all the subframes, then all the thick line segments are caused to illuminate, and if the luminance of S is that achieved by causing it to illuminate in a selected one or ones of the subframes, then a portion or portions of the thick line segments are caused to illuminate; in this case, control is performed so that the total amount of the illumination coincides with the luminance of S.

[0012]

However, the light emission loci that can actually be used are limited to those within the subframe light emission periods; therefore, in the case of the 12-SF (subframe) scheme shown in Figure 29, for example, the thick line segments shown in Figure 3 are selected.

[0013]

In Figure 3, of the three oblique lines (thick line segments) forming S', the lower right end of the uppermost thick line segment slightly penetrates into the area of T'. This is because the corresponding light-emitting block (D) is equal to one subframe (see Figure 29), and control cannot be performed so as to stop the light emission partway through the one subframe because the light emission period has entered the area of T'. Similarly, the lowermost thick line segment slightly penetrates into the area of R'. Ideally, the luminance should be made to match the original luminance, but in cases where the luminance cannot be made to perfectly match the original luminance because of the arrangement of the subframes, the light emission/non-emission in each light-emitting block is controlled so as to make the luminance as close as possible to the luminance of the original pixel S. How the light-emitting blocks to be used are determined in such cases will be explained in detail with reference to Figures 6, 7, 8, and 9.

[0014]

Figure 6 is a diagram showing the principle of determining in which pixels the light-emitting blocks forming a pixel P_n on the panel are used. To avoid confusion, a pixel on the panel is designated as P_n (the n-th pixel on the panel), and its corresponding pixels assumed on the retina are designated as P_{n-1}', P_n', P_{n+1}', and P_{n+2}'.

[0015]

First, the time t and distance dx from the starting point of the light emission of P_n to the center of the light emission of the light-emitting block taken as an attention block are calculated. When the moving direction of the image is right-to-left, if a = int (dx/one pixel width on retina) is 0, then that light-emitting block is used for the pixel P_n' on the retina (Figure 7). Similarly, it is used for P_{n+1}' if a = 1 (Figure 8), and for P_{n+2}' if a = 2 (Figure 9). When the image moves in the rightward direction, the light-emitting block can be determined in a similar way (Figures 10, 11, 12, 13, 14, an 15).

[0016]

In the case of the 12-SF scheme such as shown in Figure 29, there are seven light-emitting blocks (D blocks: redundant light-emitting blocks) that have equal light emission periods. When there are a number of light-emitting block selection patterns as shown, the light-emitting blocks are used starting from the one located at the leftmost position, in order to increase the resolution. In Figure 16, when expressing the pixel S' on the retina, the light-emitting blocks are selected preferentially in ascending order of circled numbers. This is because the distance (= dx) from the left edge of the pixel to the center position of each thick line segment (light-emitting block) increases in the order of (1), (2), ..., (7). In this figure, the uppermost light-emitting block A is not selected because there is no other light-emitting block (= redundant light-emitting block) that has the same light emission period.

The resolution increases when the light emission is concentrated in a portion of the pixel, rather than spreading the light emission ever the entire pixel. The same is true of the case where the image moves in the rightward direction (Figure 17).

[0017]

If the positions of two or more redundant light-emitting blocks coincide with each other (the value of dx is the same) because of the moving speed, the light-emitting blocks are selected in the order in which they occur along time axis. This has the effect of eliminating flicker by temporally clustering the light emissions close together in the forward direction (Figures 18 and 19).

By applying the technique of the present invention, the pixels assumed on the retina can be made finer than the actual pixels (Figures 4 and 5).

[0018]

The intra-frame pulse-count modulation method used as a grayscale display method for PDPs has the characteristic that the light emission period per TV frame for each pixel can extend at maximum over the entire length of one TV frame period. As a result, when an image moves, and the viewpoint follows it, the light emission of the pixel spreads on the retina by the number of pixels by which the image moves during the one TV frame period. If, by controlling this spreading, two pixels are virtually created within one pixel on the retina corresponding to one pixel on the panel, the resolution can be doubled in the moving direction of the image.

[0019]

When the viewpoint follows the moving image, the stimulus of the light emission that the retina receives from each pixel on the panel spreads by the number of pixels by which the image moves during the one TV frame period. Here, when the moving speed of the image is v [P/F, pixel/field], the light emission period of each subframe in one TV frame is t, and the number of

grayscales is 256, then the width over which each subframe light emission period spreads on the retina is (vt/255 + 1/3) times the width of one pixel on the retina. The unit "pixel" used here refers to the width of one pixel that is composed of three pixels of R, G and B on the panel.

[0020]

Figure 4 shows an example in which the pixels Q', R', S', and T' assumed on the retina corresponding the actual pixels Q, R, S, and T (= pixels on the panel) are each divided into n segments, while Figure 5 shows an example in which each pixel is divided into two segments. In the conventional display method, when there are, for example, four pixels Q, R, S, and T on the panel, there are also four pixels Q, R, S, and T on the retina. On the other hand, when the virtual pixel method is used, eight virtual pixels are formed on the retina, for example, in the case of Figure 5, and an image can thus be displayed with a resolution twice as high as that achieved by the pixels on the PDP. That is, for moving images, an SXGA display can be achieved on a PDP whose panel specification is VGA.

[0021]

Since the number of pixels assumed on the retina is twice the number of pixels on the actual panel, when forming two virtual pixels within the width of one pixel on the retina corresponding to one pixel on the panel, the ideal light emission loci used for forming the virtual pixel S1' are as shown by thick line segments in Figure 20.

[0022]

When using the method of the invention, it is required that the image be moving, and also that the moving direction and speed be known in advance. When the 24-SF arrangement shown in Figure 24(C) is used, the selected light-emitting blocks are as shown in Figure 21. The same applies to an image moving in the rightward direction (Figures 22 and 23).

[0023]

The subframe arrangement (= light-emitting block arrangement) of Figure 24 is characterized by being symmetrical about 0.5 F. To achieve 256 grayscales for each half pixel on the retina, two sets of subfields, each for 256 grayscales, are provided within one TV field. This is effective when determining the light-emitting blocks to be used, because when using virtual pixels created by dividing one pixel into two segments, a symmetrical light-emitting pattern can be selected for each pair of virtual pixels. When there is redundancy in the selection of light-emitting blocks, the light-emitting blocks are selected starting from the one located at the edge of the pixel when it is possible to select them spatially, or the light-emitting blocks are selected in the order in which they occur along time axis when it is possible to select them temporally (Figures 25 to 28).

[0024]

As an example, consider the case where an image moves leftward at a speed of 3[P/F] when the 24-SF scheme is used. In Figure 21, the oblique dashed lines show the light emission loci of the pixels Q, S, R and T of the same color on the panel. Because the image moves and the viewpoint follows it, the light emission period of each subframe is dispersed on the retina. If data for two pixels are arranged within one pixel width on the retina by controlling the light emitting positions, the resolution can be doubled. That is, when the light-emitting blocks indicated by the left halves of the thick lines are selected, the stimulus of the light emission received on the retina is S_1', and when the light-emitting blocks indicated by the right halves of the thick lines are selected, the stimulus of the light emission received on the retina is S_2', the width of each thus being one-half pixel. Since one light-emitting block A and seven light-emitting blocks D are contained in the left halves as well as in the right halves of the thick lines, 256 grayscales can be displayed by combining them. In this way, when the virtual pixel method is used, the

resolution can be doubled by creating visually recognizable pixels Q_1', Q_2', R_1', R_2', S_1', S_2', T_1', and T_2' for the pixels, Q, R, S, and T on the panel. However, the luminance between pixels does not become zero, but one overlaps into the other.

[0025]

Figure 35 shows the calculation results of contrast $(B_{max} - B_{min})/(B_{max} + B_{min})$ when a stripe pattern of 0-255-0-255 moving at speeds of 1 to 19[P/F] is displayed with SXGA resolution, twice the VGA resolution of the panel, by using the virtual pixel method for the four different subframe arrangement schemes shown in Figure 24.

[0026]

As the speed of motion of the image increases, the contrast decreases. This is because the positional spreading of subframe light emission increases in proportion to the speed of motion. Figure 36 shows the range of speeds where the contrast is 0.2 and higher and the range of speeds where the contrast is 0.5 and higher for the respective subframe arrangement schemes. In a conventional television signal, the frequency of appearance of a moving image decreases as the speed of motion increases; for example, the frequency of appearance of an image at 10[P/F] is about 10% of that of an image at 1[P/F]. It can therefore be seen that 24 or more SFs are needed if an image with a contrast of 0.5 or higher is to be displayed within the range of speeds of 1 to 10[P/F]. Since the spreading of light emission depends on the subframe whose light emission period is the longest of all the subframes constituting one TV frame, the light emission period of this subframe should be made as short as possible to obtain a satisfactory effect.

[0027]

When the resolution of the input image is SXGA, and the resolution of the display PDP is VGA, in the conventional method the image is displayed on the PDP after converting it from SXGA to VGA, and the resolution of the image visually

recognized is therefore VGA. On the other hand, when the virtual pixel method is used, the image data with SXGA resolution can be input as is with respect to the moving direction, and the resolution of the image visually recognized is SXGA in the moving direction though the resolution of the PDP used for display is VGA.

[0028]

Figure 37 shows the result of the verification of this method done by using computer simulation. The numbers shown in the figure indicate grayscale levels. When the input image is a monochrome pattern of 1-0-1-0- with SXGA resolution (a), in the conventional method the pattern becomes a uniform pattern of a value intermediate between 0 and 1, for example, 0.5, depending on the sampling timing, and the stripe pattern cannot be reproduced (b). However, when the virtual pixel method is used, the original image can be correctly reproduced (c).

[0029]

On the other hand, when the input is a VGA image, if the input image information is increased by interpolation and the image is displayed using the virtual pixel method, the image for viewing can be displayed with SXGA resolution in the moving direction. Figure 38 shows an example in which this effect was verified through computer simulation. Data for two pixels can be input within the width of one pixel of VGA resolution, and finer detail can thus be reproduced.

[0030]

When the virtual pixel method of the invention is used, if the resolution of the PDP used for display is VGA, the amount of information that has been increased by two times in the moving direction can be input. Therefore, when the input is an SXGA image, the image can be accurately reproduced; further, when the input is a VGA image, the amount of information of the image to be presented for viewing can be increased by two times by using an interpolation method or the like.

[0031]

The technique of the invention is effective in eight moving directions, i.e., the horizontal directions, the vertical directions, and the directions in which the diagonally neighboring pixels are located. Further, since the virtual pixel method is a technique for enhancing the resolution of moving images based only on signal processing, there is no need to change the panel structure. However, to obtain satisfactory grayscale display characteristics, a sufficient number of subframes that can reproduce 512 grayscales must be provided in one TV frame, and switching speed twice as fast as that in the conventional system is required. As present, since 32-SF driving is proven in the NTSC double scan system, the 24-SF scheme described herein is feasible.

[0032]

Next, consider the case where the virtual pixel method is applied to the reproduction of colors. Usually, white color is reproduced by using three sub-pixels R, G, and B spatially arranged in the horizontal direction, but when the virtual pixel method is used, white color can be rendered by using three sub-pixels "temporally arranged" as shown in Figure 30. This makes it possible to reduce the width necessary to render white color, and thus the resolution greatly improves. In Figure 30, one light-emitting block is selected for each of the RGB colors, but alternatively, a plurality of light-emitting blocks can be selected for each color. All the other colors can be reproduced by varying the proportions among the R, G, and B.

[0033]

When a slit is provided in the light extracting portion of each discharge cell, the effectiveness of the technique that enhances the resolution by using the virtual pixel method further increases. That is, when such a slit is provided, the width of the light that emerges from the actual panel becomes smaller than it would be if the slit were not provided; as a result, the number of virtual pixels can be increased

correspondingly. For example, when the slit width is reduced to 1/n of the original width 1, theoretically the number of virtual pixels can be increased by a factor of n at maximum.

[0034]

The slit may be formed in the shape of a cross by cutting horizontal and vertical lines. In this case, the number of virtual pixels can be increased in both the horizontal and vertical directions. When such a slit is provided, the portion that faces the discharge cell may be coated with a phosphor, which provides an effective means of enhancing the luminance. Each virtual pixel can be formed with a width substantially equal to the slit width.

[0035]

Based on the present invention, the description of the drawings will be summarized as follows:

[0036]

Figure 1: Pixels Q', R', S', and T' corresponding to the pixels Q, R, S, and T to be displayed are formed on the retina.

[0037]

Figure 2: When the image moving direction is right-to-left, the light emissions of the pixels on the PDP panel leave loci on the retina as indicated by the dashed lines in the figure. These loci are ingeniously used when expressing the pixels assumed on the retina. For example, when expressing the pixel S' assumed on the retina, ideally the light emission loci indicated by the thick lines lying within the width of S' are used as shown.

[0038]

Figure 3: The light emission loci that can actually be used are limited to those within the subframe light emission periods; therefore, in the case of the 12-SF scheme shown in Figure 29, for example, the light emission periods of the thick line segments shown in the figure are used to express the pixel S' on the retina.

[0039]

Figure 4: The pixels assumed on the retina are each set finer than the one pixel on the retina that corresponds to one pixel on the panel. The thus set pixels are called the virtual pixels.

[0040]

Figure 5: The width of each virtual pixel is set one-half that of the one pixel on the retina that corresponds to one pixel on the panel.

[0041]

Figure 6: Determines in which pixels the light-emitting blocks forming the pixel P_n on the panel are used when the moving direction of the image is right-to-left. First, the time t and distance dx from the starting point of the light emission of P_n to the center of the light emission of the light-emitting block taken as an attention block are calculated.

[0042]

Figure 7: When the moving direction of the image is right-to-left, if a = int (dx/one pixel width on retina) is 0, then the light-emitting block is used for the pixel P_n' on the retina.

[0043]

Figure 8: When the image a = 1, the light-emitting block is used for P_{n+1}'.

[0044]

Figure 9: When the image a = 2, the light-emitting block is used for P_{n+2}'.

[0045]

Figure 10: When the image moving direction is left-to-right, the light emissions of the pixels on the PDP panel leave loci on the retina as indicated by the dashed lines in the figure. When expressing the pixel R' assumed on the retina, ideally the light emission loci indicated by the thick lines lying within the width of R' are used as shown.

[0046]

Figure 11: The light emission loci that can actually be used are limited to those within the subframe light emission periods; therefore, in the case of the 12-SF scheme shown in Figure 29, for example, the light emission periods of the thick line segments shown in the figure are used to express the pixel S' on the retina.

[0047]

Figure 12: Determines in which pixels the light-emitting blocks forming the pixel P_n on the panel are used when the moving direction of the image is left-to-right. The time t and distance dx from the starting point of the light emission of P_n to the center of the light emission of the light-emitting block taken as an attention block are calculated.

[0048]

Figure 13: When the moving direction of the image is left-to-right, if a = int (dx/one pixel width on retina) is 0, then the light-emitting block is used for the pixel P_{n-1}' on the retina.

[0049]

Figure 14: When the image a = 1, the light-emitting block is used for P_{n-2}'.

[0050]

Figure 15: When the image a = 2, the light-emitting block is used for P_{n-3}'.

[0051]

Figure 16: In the case of the 12-SF scheme, there are seven light-emitting blocks D (redundant light-emitting blocks) that have equal light emission periods. When expressing the pixel S' on the retina, the light-emitting blocks are used starting from the one located at the leftmost position, in order to increase the resolution. When the moving direction of the image is right-to-left, the light-emitting blocks are used in the order as shown in the figure.

[0052]

Figure 17: When the moving direction of the image is left-

to-right, the light-emitting blocks are selected in sequence starting from the left side.

[0053]

Figure 18: When the positions of two or more redundant light-emitting blocks coincide with each other because of the moving speed, and when the moving direction of the image is right-to-left, the light-emitting blocks are selected as shown in the figure in the order in which they occur along time axis.

[0054]

Figure 19: When the positions of two or more redundant light-emitting blocks coincide with each other because of the moving speed, and when the moving direction of the image is left-to-right, the light-emitting blocks are selected as shown in the figure in the order in which they occur along time axis.

[0055]

Figure 20: When forming two virtual pixels within the width of one pixel on the retina corresponding to one pixel on the panel, the ideal light emission loci used for forming the virtual pixel S1' are as shown by thick line segments in the figure.

[0056]

Figure 21: The light emission loci used for forming the virtual pixels S1' and S2' when the 24-SF scheme shown in Figure 24(c) is used.

[0057]

Figure 22: The ideal light emission loci used for forming the virtual pixel S1' when the moving direction is left-to-right.

[0058]

Figure 23: The ideal light emission loci used for forming the virtual pixels S1' and S2' when the moving direction is left-to-right.

[0059]

Figure 24: The subframe arrangement used in the virtual pixel method. The arrangement is characterized by being

symmetrical about 0.5 F.

[0060]

Figure 25: A method of selecting redundant light-emitting blocks for a virtual pixel 1 (a virtual pixel with a subscript 1) when the moving direction is right-to-left.

[0061]

Figure 26: A method of selecting redundant light-emitting blocks for a virtual pixel 2 (a virtual pixel with a subscript 2) when the moving direction is right-to-left.

[0062]

Figure 27: A method of selecting redundant light-emitting blocks for a virtual pixel 1 when the moving direction is left-to-right.

[0063]

Figure 28: A method of selecting redundant light-emitting blocks for a virtual pixel 2 when the moving direction is left-to-right.

[0064]

Figure 29: 12-SF (subframe) arrangement.

Figure 30: Usually, white color is reproduced by using three RGB pixels spatially arranged in the horizontal direction, but when the virtual pixel method is used, white color is reproduced by using three RGB pixels temporally arranged as shown in the figure.

[0065]

Figure 31: The structure (cross-sectional view) of the plasma display apparatus according to the present invention.

[0066]

Figure 32: The structure (front view) of the plasma display apparatus according to the present invention. A horizontally extending slit is formed.

[0067]

Figure 33: The structure (front view) of the plasma display apparatus according to the present invention. A vertically extending slit is formed.

[0068]

Figure 34: The structure (front view) of the plasma display apparatus according to the present invention. A cross-shaped slit is formed by cutting along horizontal and vertical directions.

Based on the embodiments described above, the present invention can be summarized as follows:

(Note 1)

A method of driving a display device that comprises a means for controlling the light emission of each pixel in the display device by using a plurality of subframes into which one frame period for forming an image is divided, and that displays an image moving at a given speed on a display screen, wherein the method assumes on a retina a particular pixel to be focused on the retina, and controls the light emission in each subframe so that the luminance of the pixel on the retina becomes substantially equal to the luminance of an input image.

(Note 2)

The method of driving a display device as described in note 1, wherein the light emission in each subframe is controlled so that the luminous color of the pixel on the retina becomes substantially equal to the luminous color of the input image.

(Note 3)

The method of driving a display device as described in note 1 or 2, wherein the light emission in each subframe is controlled so that a locus that the light emission of the pixel leaves on the retina substantially falls within the width of the corresponding pixel on the retina.

(Note 4)

The method of driving a display device as described in any one of notes 1 to 3, wherein the pitch of the pixels on the retina is chosen to be smaller than the pitch of the pixels forming the display device.

(Note 5)

The method of driving a display device as described in note 4, wherein the pitch of the pixels on the retina is chosen to be one-half of the pitch of the pixels forming the display device.

(Note 6)

The method of driving a display device as described in note 5, wherein, in a scheme in which the grayscale of each pixel on the retina is expressed using one set of n subframes per frame period, two sets of n subframes are provided per frame period for each of the pixels forming the display device.

(Note 7)

The method of driving a display device as described in note 6, wherein for each of the pixels forming the display device, the two sets of n subframes are arranged one in the first half of one frame period and the other in the second half.

(Note 8)

The method of driving a display device as described in any one of notes 1 to 7, wherein when there is redundancy in selecting the subframes in which the light emission is to be controlled, the control is performed by preferentially selecting the subframe focused closer to an edge position on the retinal than the others.

(Note 9)

The method of driving a display device as described in note 8, wherein the control is performed by preferentially selecting the subframe capable of emitting light earlier than the others.

(Note 10)

The display device described in any one of notes 1 to 9, wherein a slit is provided in a light extracting portion of each discharge cell to restrict the effective area of the light extracting portion.

(Note 11)

The display device described in note 10, wherein the slit

is formed in the shape of a vertically or horizontally extending line, or in the shape of a cross by combining a vertically extending line and a horizontally extending line.

(Note 12)

The display device described in note 10 or 11, wherein to form the slit, a light-shielding dielectric is provided on a front substrate, and the observer side of the light-shielding dielectric is made black, while the opposite side of the light-shielding dielectric from the observer side is made white.

(Note 13)

The display device described in note 12, wherein an inner wall surface of the light-shielding dielectric is coated with an ultraviolet-excited phosphor.

[0069]

[ADVANTAGEOUS EFFECT OF THE INVENTION]

According to the present invention, by using the virtual pixel technique, it becomes possible to reduce the moving image false contour and achieve a high-resolution display. Further, bright-room contrast increases. Furthermore, by increasing the phosphor-coated area, the luminance and the light emission efficiency can be enhanced.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Figure 1]

Pixels to be displayed and their corresponding pixels assumed on the retina. (In the case of a still image)

[Figure 2]

Loci of light emissions of pixels on the panel which are used for expressing the pixel S' assumed on the retina. (Ideal case)

[Figure 3]

Loci of light emissions of pixels on the panel which are used for expressing the pixel S' assumed on the retina. (When light-emitting blocks are considered)

[Figure 4]

Pixels on the panel and pixels assumed on the retina at a

finer pitch than the pixels on the panel. (Virtual pixels)

[Figure 5]

Pixels on the panel and pixels assumed on the retina by diving each pixel on the panel into two segments. (Virtual pixels)

[Figure 6]

Time and distance to the center of the light emission locus of a light-emitting block taken as an attention block in a pixel P_n on the panel.

[Figure 7]

A case where a = 0.

[Figure 8]

A case where a = 1.

[Figure 9]

A case where a = 2.

[Figure 10]

Loci of light emissions of pixels on the panel which are used for expressing the pixel S' assumed on the retina. (Ideal case)

[Figure 11]

Loci of light emissions of pixels on the panel which are used for expressing the pixel S' assumed on the retina. (When light-emitting blocks are considered)

[Figure 12]

Time and distance to the center of the light emission locus of a light-emitting block taken as an attention block in a pixel P_n on the panel.

[Figure 13]

A case where a = 0.

[Figure 14]

A case where a = 1.

[Figure 15]

A case where a = 2.

[Figure 16]

The order of selection of redundant light-emitting blocks.

(Moving direction is right-to-left)

[Figure 17]

The order of selection of redundant light-emitting blocks. (Moving direction is left-to-right)

[Figure 18]

The order of selection of redundant light-emitting blocks when their positions on the retina coincide with each other. (Moving direction is right-to-left)

[Figure 19]

The order of selection of redundant light-emitting blocks when their positions on the retina coincide with each other. (Moving direction is left-to-right)

[Figure 20]

Loci of light emissions of pixels on the panel which are used for expressing a virtual pixel S_1'. (Ideal case)

[Figure 21]

Loci of light emissions of pixels on the panel which are used for expressing virtual pixels S_1' and S_2'. (When light-emitting blocks are considered)

[Figure 22]

Loci of light emissions of pixels on the panel which are used for expressing a virtual pixel S_1'. (Ideal case)

[Figure 23]

Loci of light emissions of pixels on the panel which are used for expressing virtual pixels S_1' and S_2'. (When light-emitting blocks are considered)

[Figure 24]

A subframe arrangement in the virtual pixel method.

[Figure 25]

The order of selection of redundant light-emitting blocks in the virtual pixel S_1'. (Moving direction is right-to-left)

[Figure 26]

The order of selection of redundant light-emitting blocks in the virtual pixel S_2'. (Moving direction is right-to-left)

[Figure 27]

The order of selection of redundant light-emitting blocks in the virtual pixel S_1'. (Moving direction is left-to-right)

[Figure 28]

The order of selection of redundant light-emitting blocks in the virtual pixel S_2'. (Moving direction is left-to-right)

[Figure 29]

A subframe arrangement in 12 SF.

[Figure 30]

Rendition of white color using orderly arranged three RGB pixels.

[Figure 31]

The structure of a plasma display.

[Figure 32]

A slit formed in a vertical direction.

[Figure 33]

A slit formed in a horizontal direction.

[Figure 34]

A slit formed in the shape of a cross.

[Figure 35]

Relationship between speed of motion and contrast.

[Figure 36]

Relationship between speed of motion and the number of subframes.

[Figure 37]

Simulation result showing the improvement of resolution.

[Figure 38]

Simulation result when an interpolation method is also used.

[NAME OF DOCUMENT] ABSTRACT

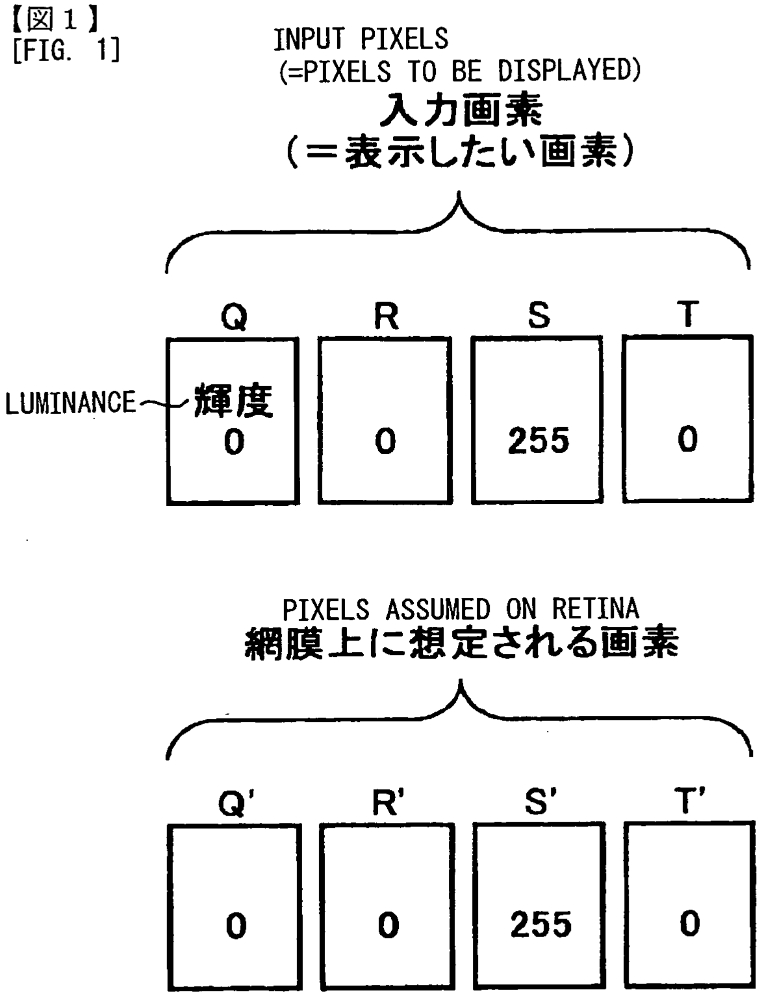
[ABSTRACT]

[OBJECT] The present invention concerns a technique for improving image quality and achieving a high-resolution image display in a display device, such as a plasma display panel (PDP), that reproduces grayscales by using a time-division display method, and an object of the invention is to alleviate the problem of edge blurring and to achieve a high-resolution image display without changing existing panel specifications.

[CONSTITUTION] A method of driving a display device that comprises a means for controlling the light emission of each pixel in the display device by using a plurality of subframes into which one frame period for forming an image is divided, and that displays an image moving at a given speed on a display screen, wherein the method assumes on a retina a particular pixel to be focused on the retina, and controls the light emission in each subframe so that the luminance of the pixel on the retina becomes substantially equal to the luminance of an input image.

[SELECTED DRAWING] Figure 2

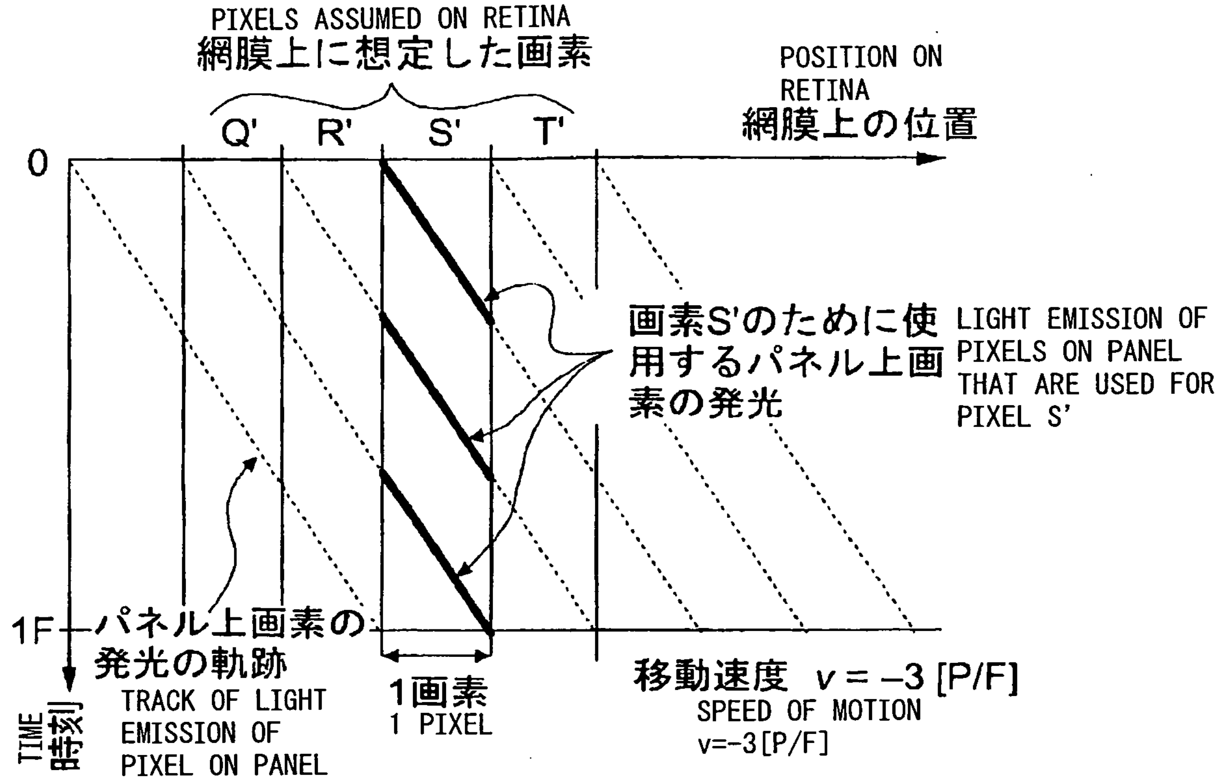
【図1】
[FIG. 1]



表示したい画素とそれに対応して網膜上に想定した画素
(静止画の場合)

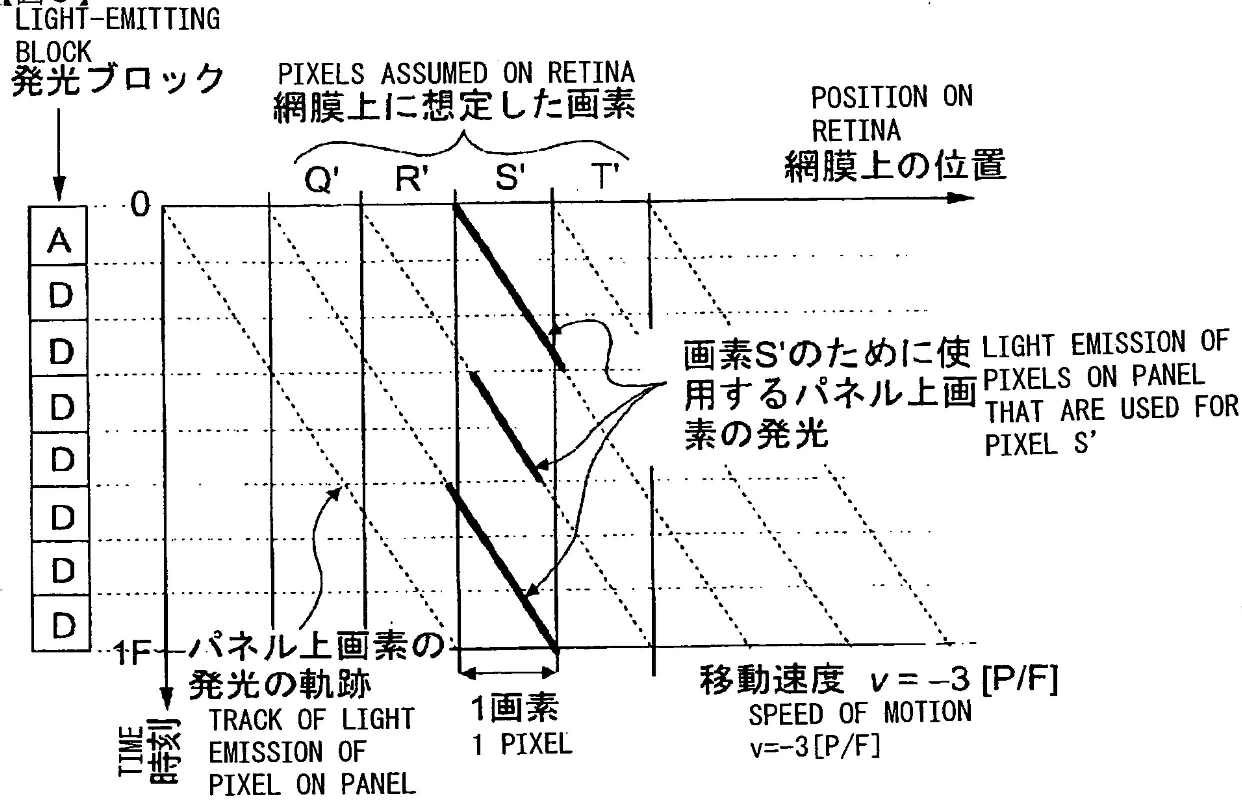
PIXELS TO BE DISPLAYED AND THEIR CORRESPONDING PIXELS ASSUMED ON THE RETINA(IN THE CASE OF A STILL IMAGE)

【図２】
[FIG. 2]



網膜上に想定した画素S'の表現のために使用するパネル上の画素の発光の軌跡（理想的な場合）
LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING THE PIXEL S' ASSUMED ON THE RETINA(IDEAL CASE)

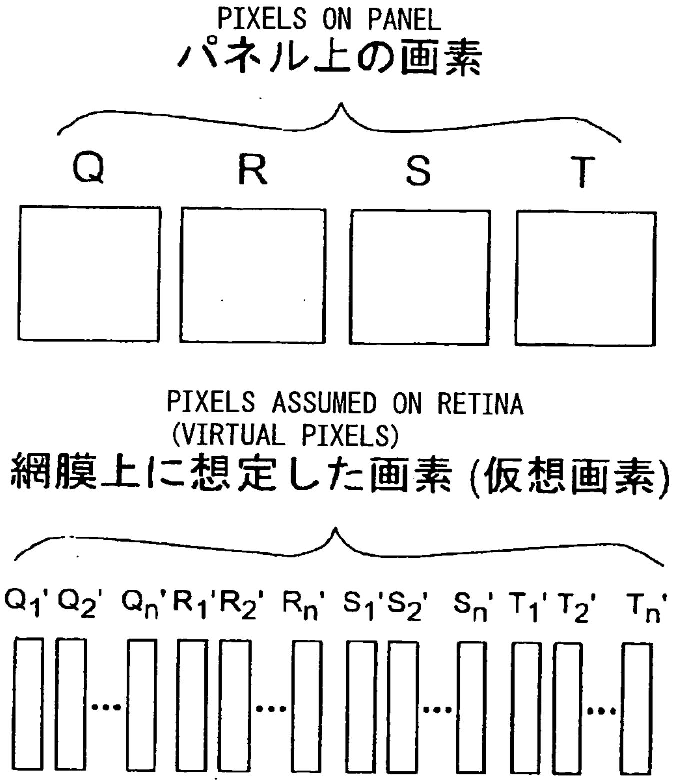
[FIG. 3]
【図３】



網膜上に想定した画素S'の表現のために使用するパネル上の画素の発光の軌跡（発光ブロックを考慮した場合）

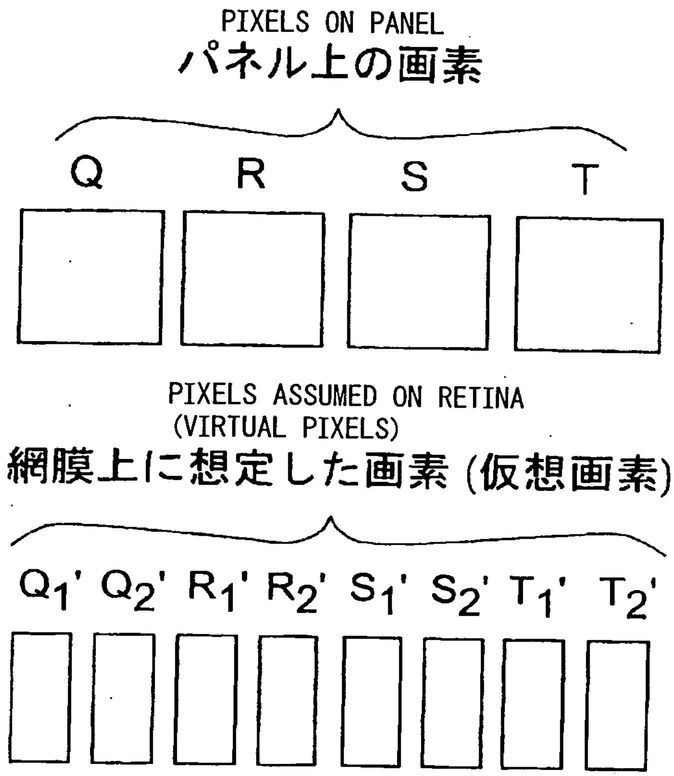
LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING THE PIXEL S' ASSUMED ON THE RETINA (WHEN LIGHT-EMITTING BLOCKS ARE CONSIDERED)

【図４】
[FIG. 4]



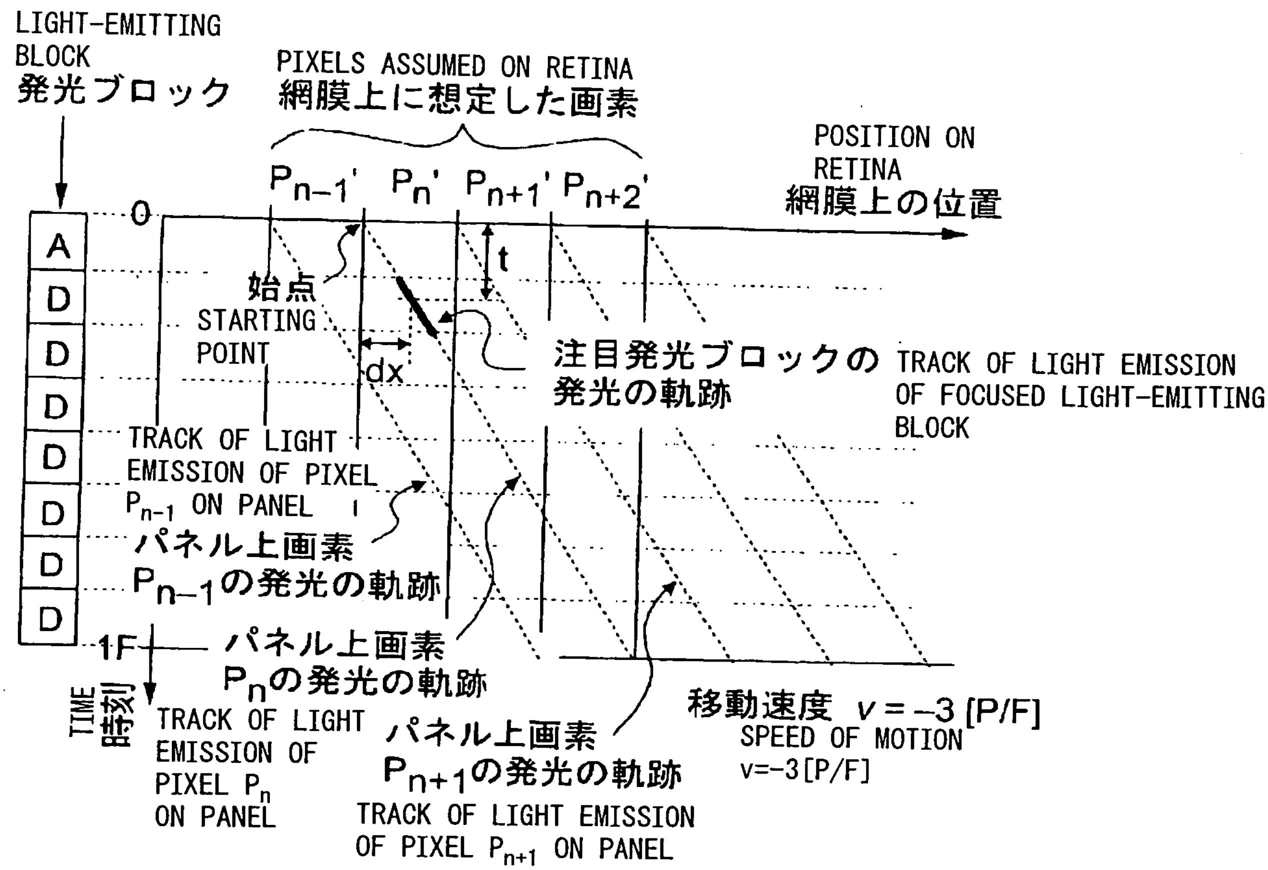
パネル上の画素とそれより細かく網膜上に想定した画素 (仮想画素)
PIXELS ON THE PANEL AND PIXELS ASSUMED ON THE RETINA AT A FINER PITCH THAN THE PIXELS ON THE PANEL(VIRTUAL PIXELS)

【図５】
[FIG. 5]



パネル上の画素とそれを1/2分割して網膜上に想定した画素 (仮想画素)
PIXELS ON THE PANEL AND PIXELS ASSUMED ON THE RETINA BY DIVING EACH PIXEL ON THE PANEL INTO TWO SEGMENTS(VIRTUAL PIXELS)

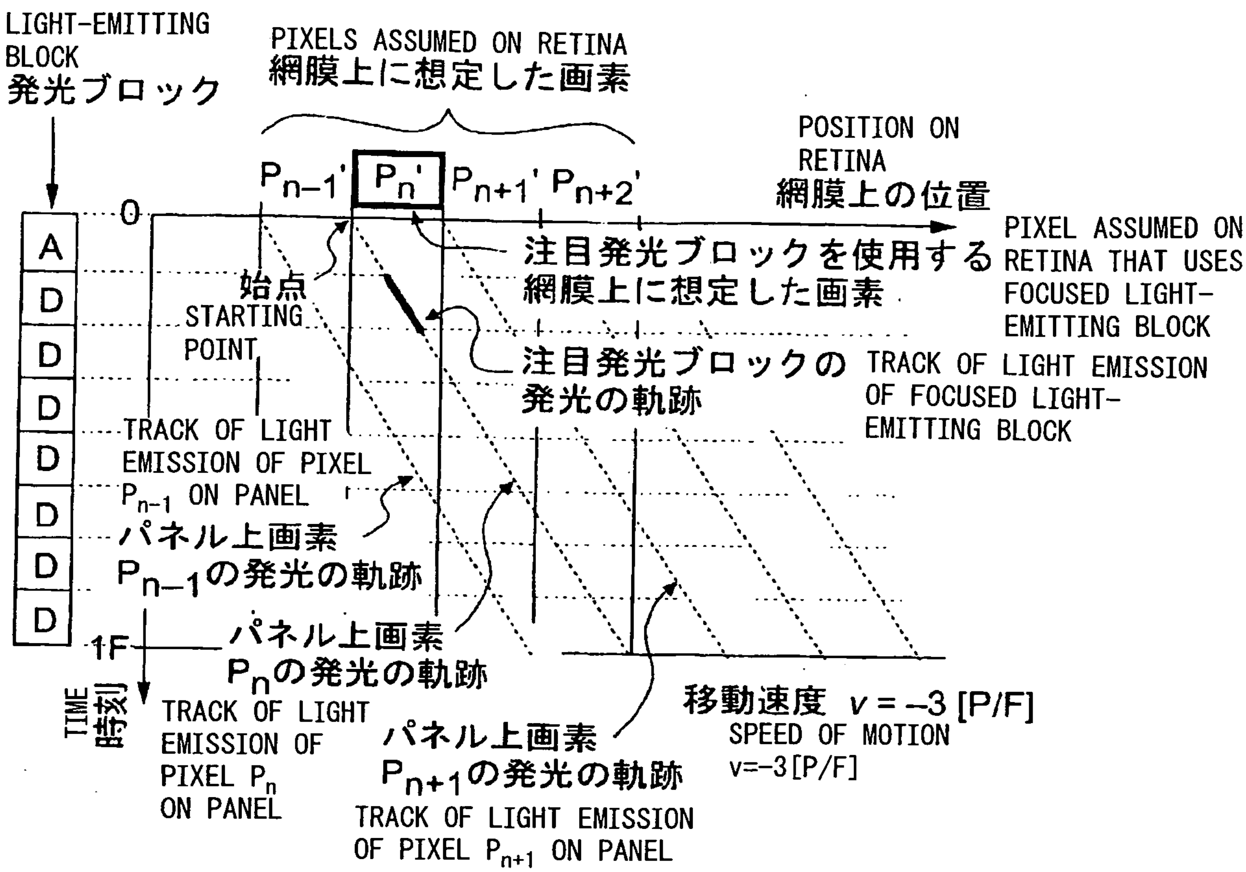
[FIG. 6]
【図６】



パネル上の画素P_nにおける注目発光ブロックの発光の軌跡の中心までの時間と距離

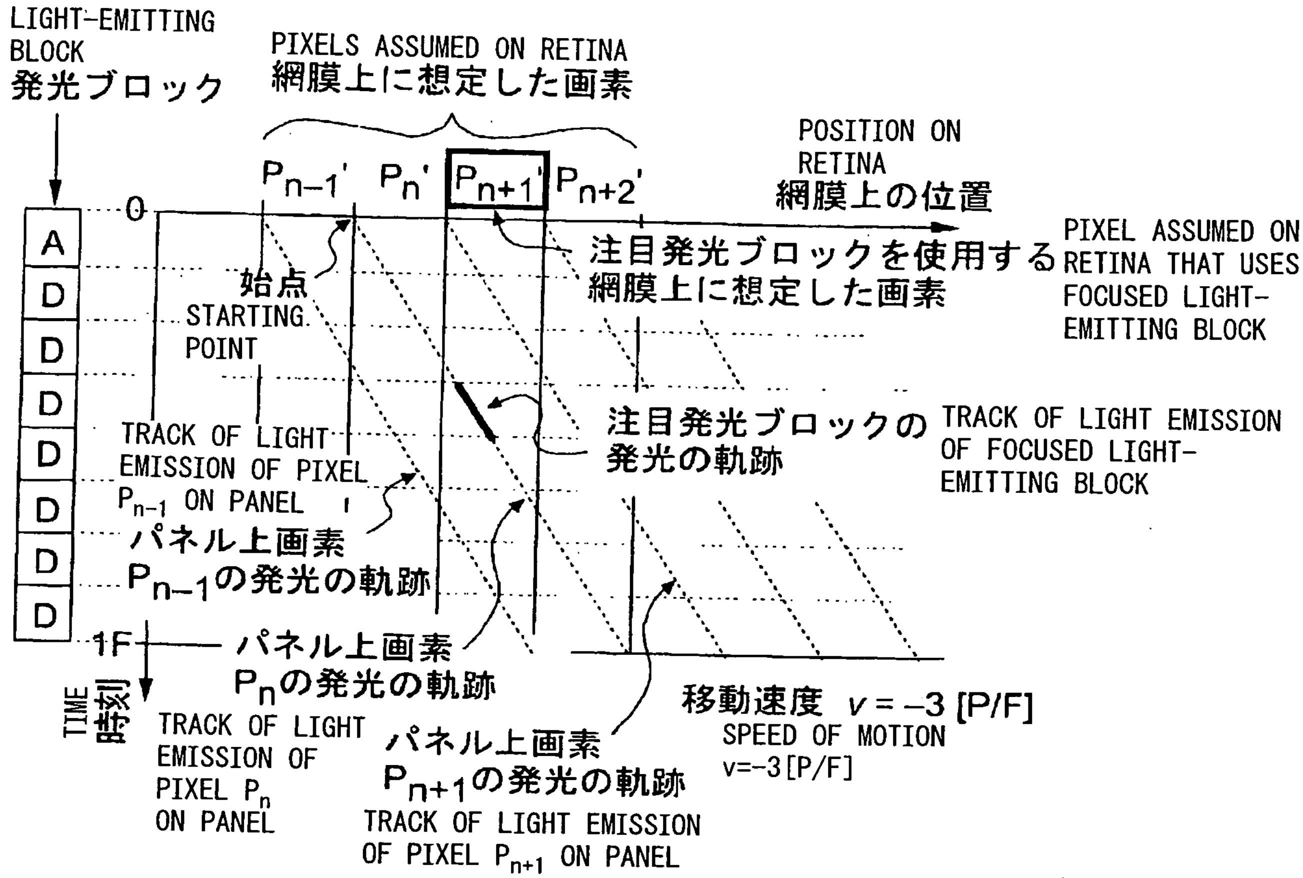
TIME AND DISTANCE TO THE CENTER OF THE LIGHT EMISSION LOCUS OF A LIGHT-EMITTING BLOCK TAKEN AS AN ATTENTION BLOCK IN A PIXEL P_n ON THE PANEL

[FIG. 7]
【図7】



a=0の場合
CASE WHERE a=0

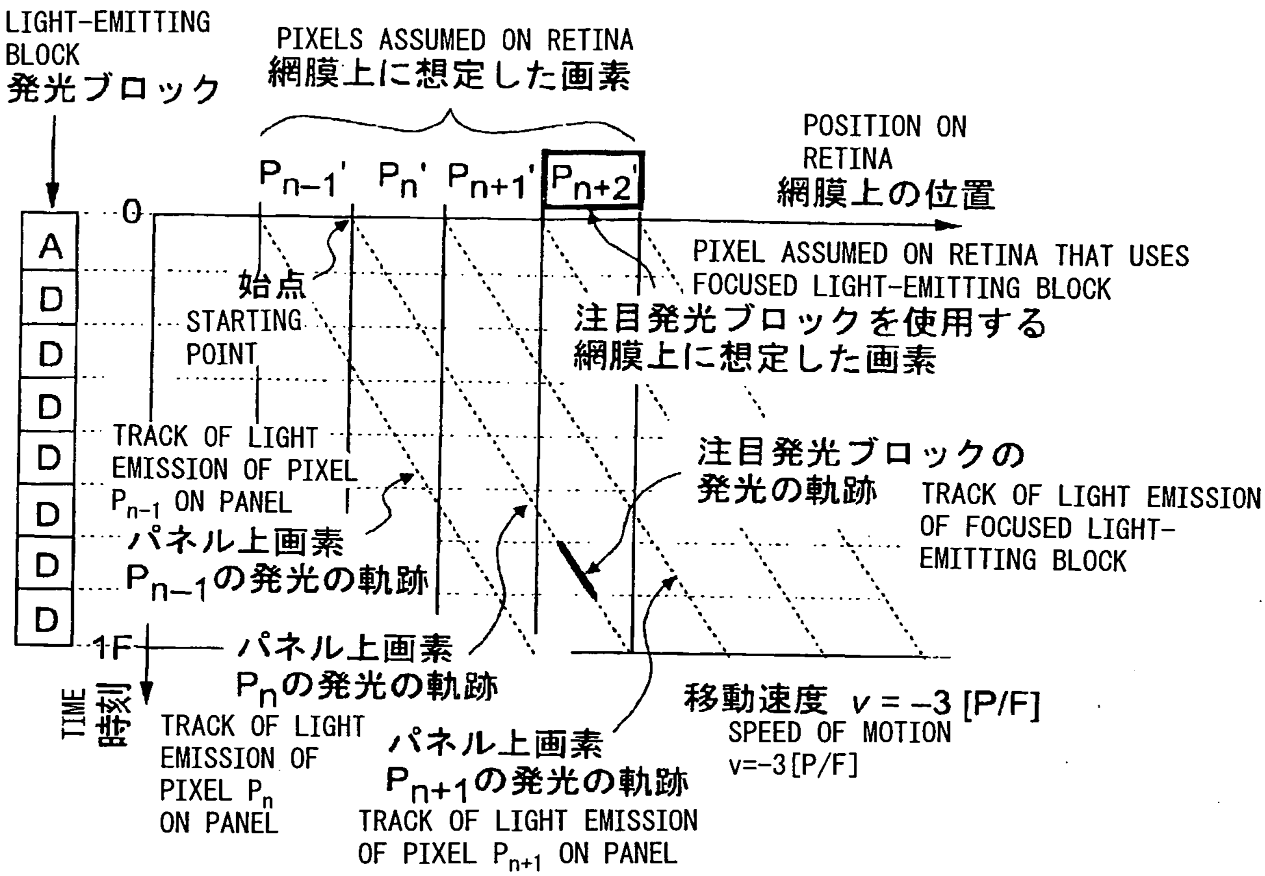
[FIG. 8]
【図8】



a=1の場合

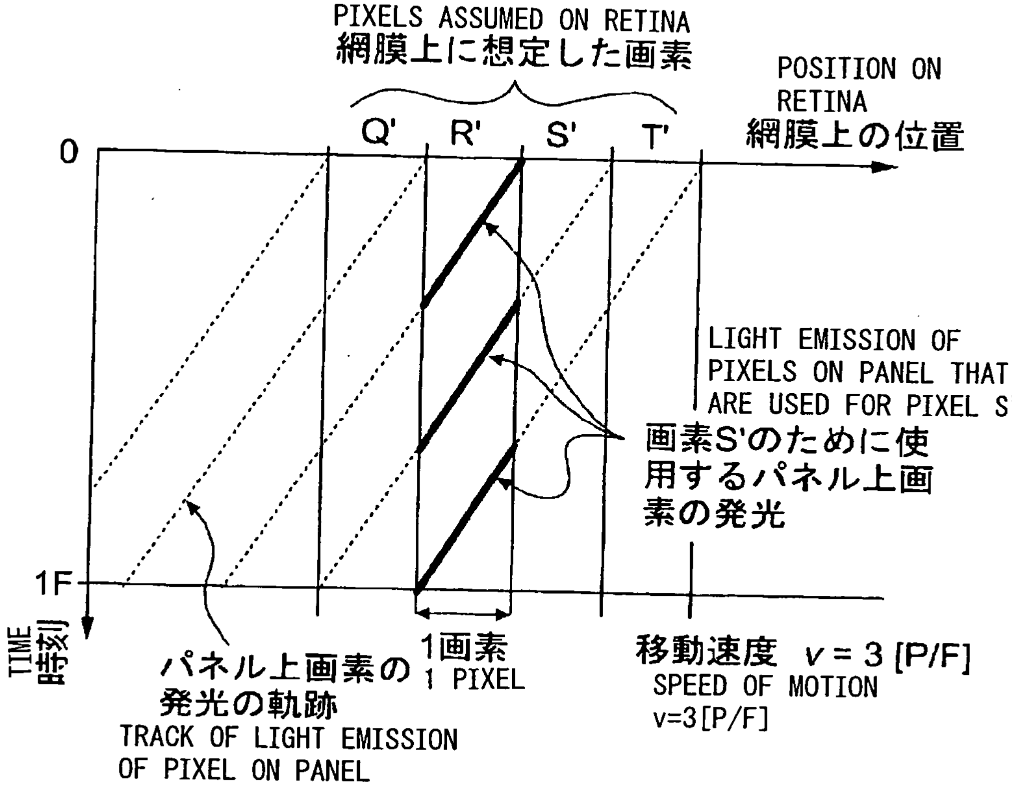
CASE WHERE a=1

[FIG. 9]
【図9】



a=2の場合
CASE WHERE a=2

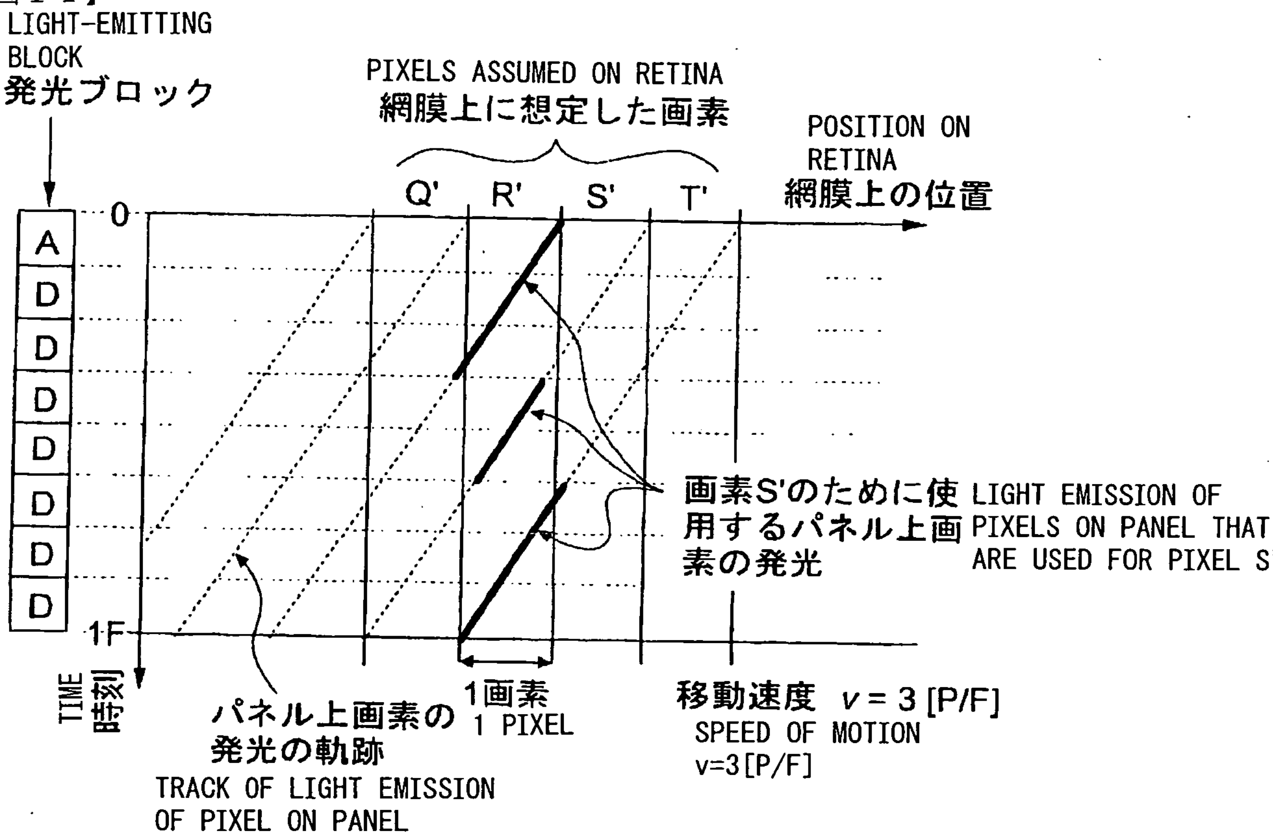
【図１０】
[FIG. 10]



網膜上に想定した画素S'の表現のために使用するパネル上の画素の発光の軌跡（理想的な場合）
LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING THE PIXEL S' ASSUMED ON THE RETINA(IDEAL CASE)

整理番号:00-01273

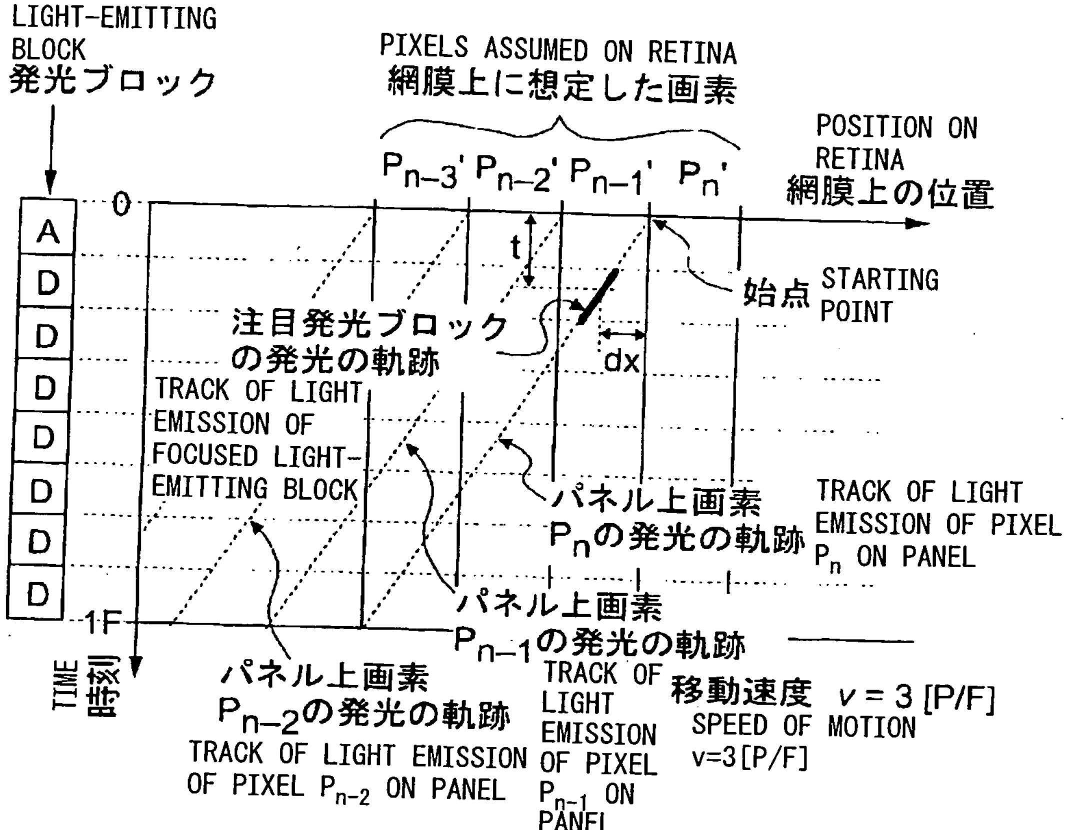
[FIG. 11]
【図１１】



網膜上に想定した画素S'の表現のために使用するパネル上の画素の発光の軌跡（発光ブロックを考慮した場合）

LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING THE PIXEL S' ASSUMED ON THE RETINA (WHEN LIGHT-EMITTING BLOCKS ARE CONSIDERED)

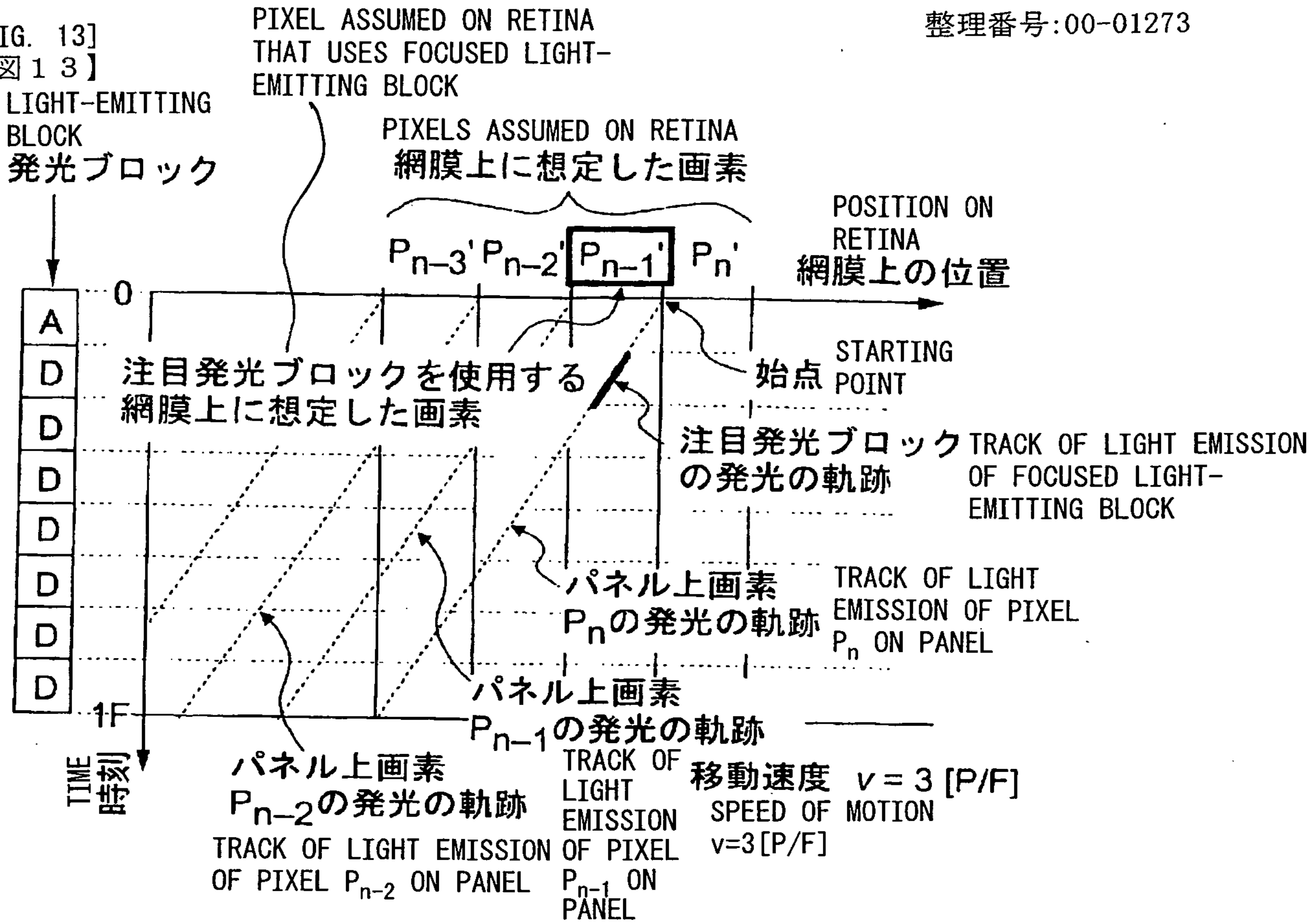
[FIG. 12]
【図１２】



パネル上の画素P_nにおける注目発光ブロックの発光の軌跡の中心までの時間と距離

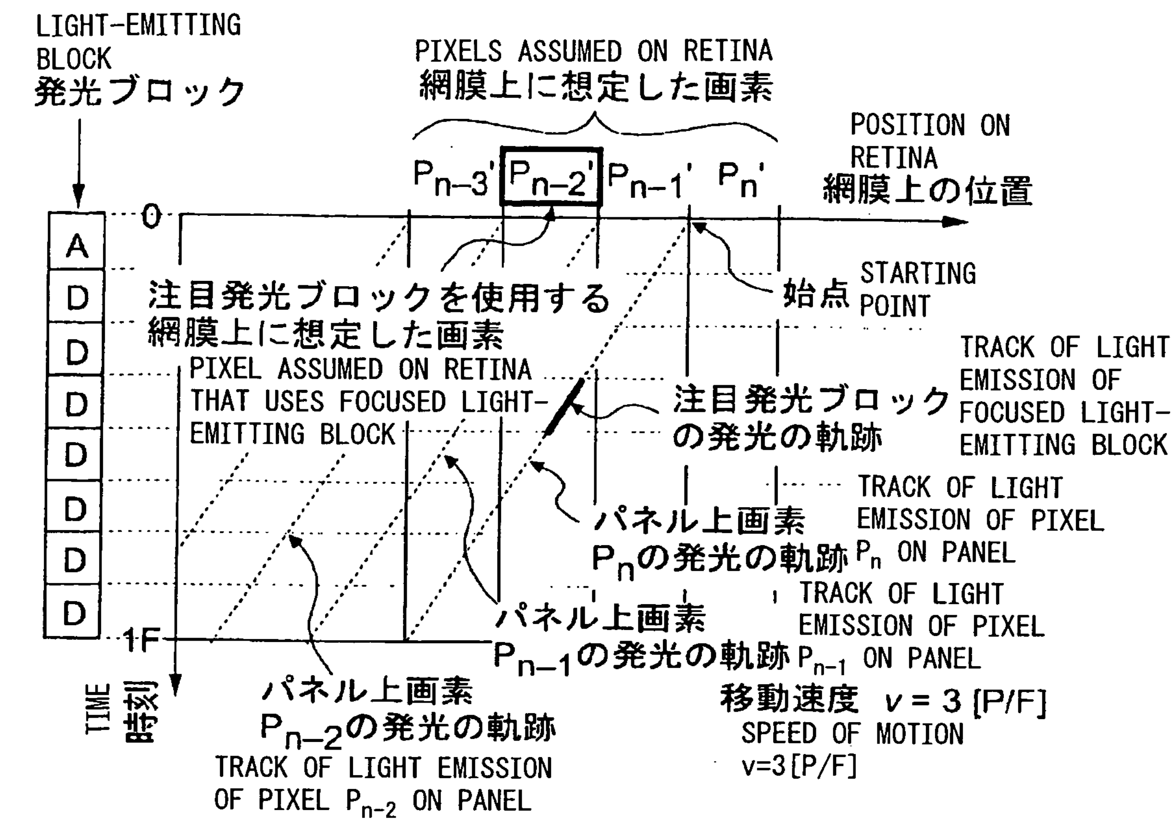
TIME AND DISTANCE TO THE CENTER OF THE LIGHT EMISSION LOCUS OF A LIGHT-EMITTING BLOCK TAKEN AS AN ATTENTION BLOCK IN A PIXEL P_n ON THE PANEL

[FIG. 13]
【図１３】



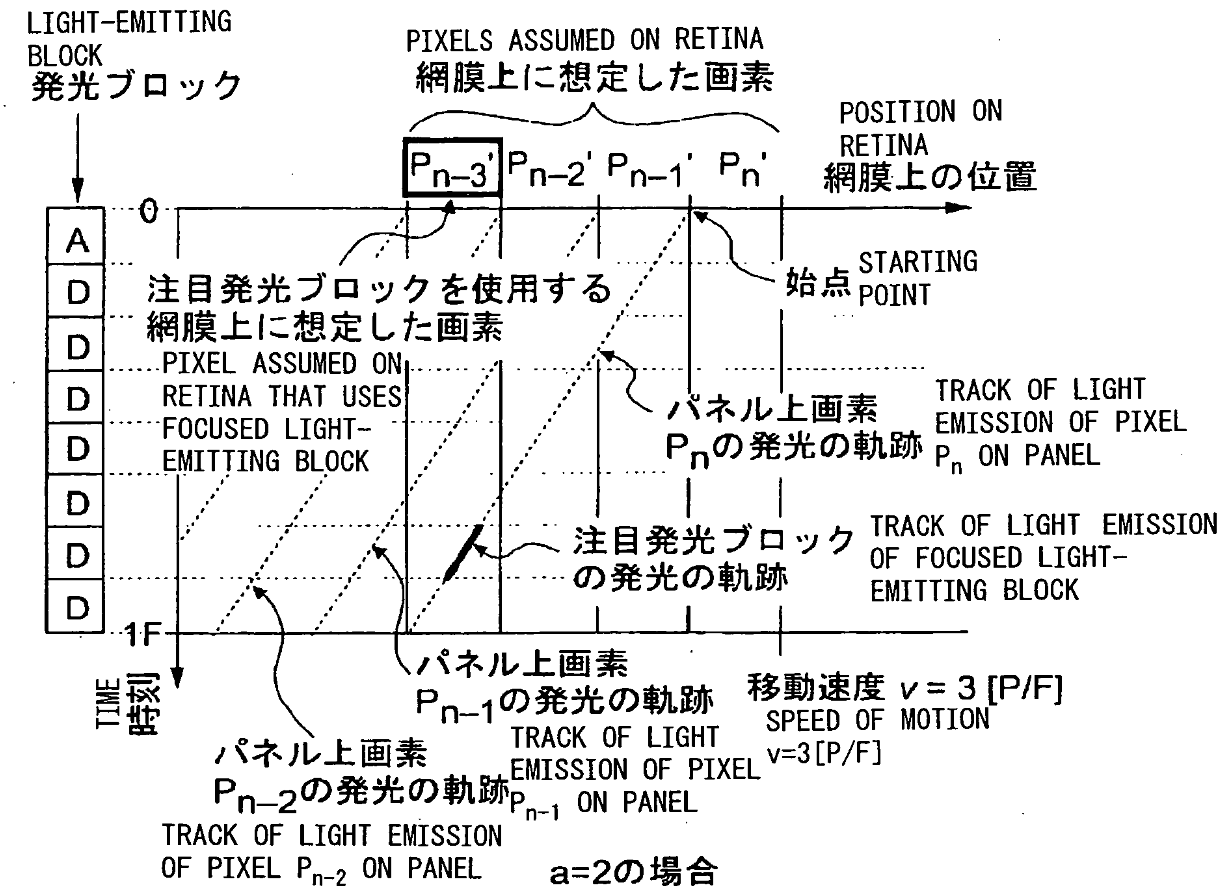
a=0の場合
CASE WHERE a=0

[FIG. 14]
【図１４】



a=1の場合
CASE WHERE a=1

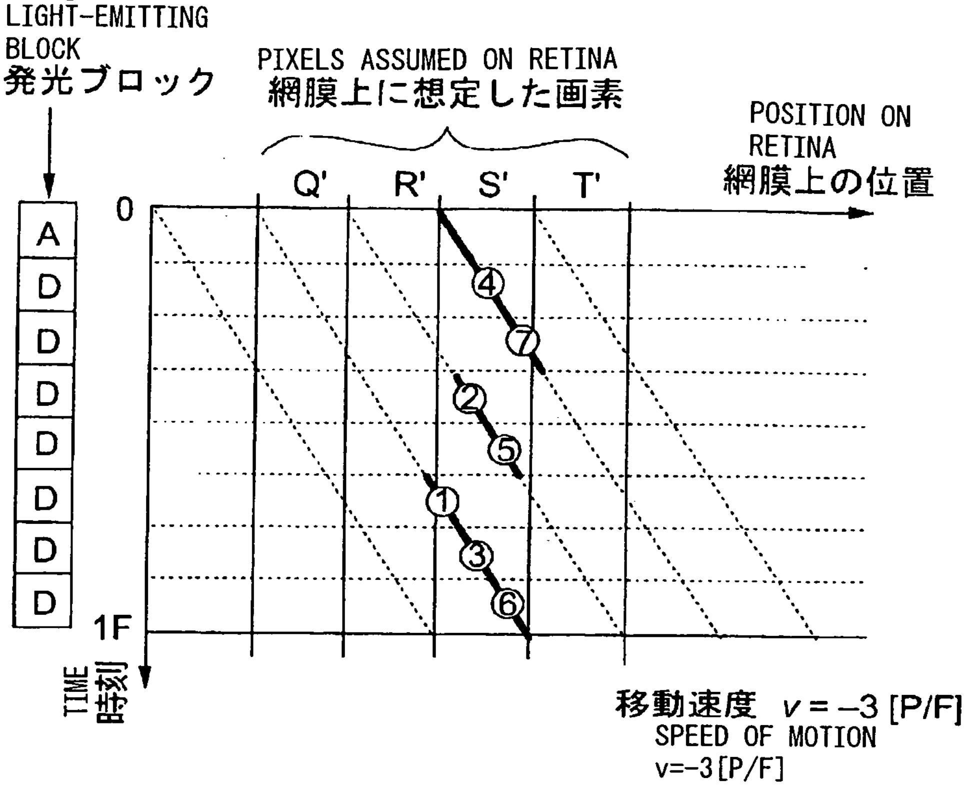
[FIG. 15]
【図１５】



a=2の場合
CASE WHERE a=2

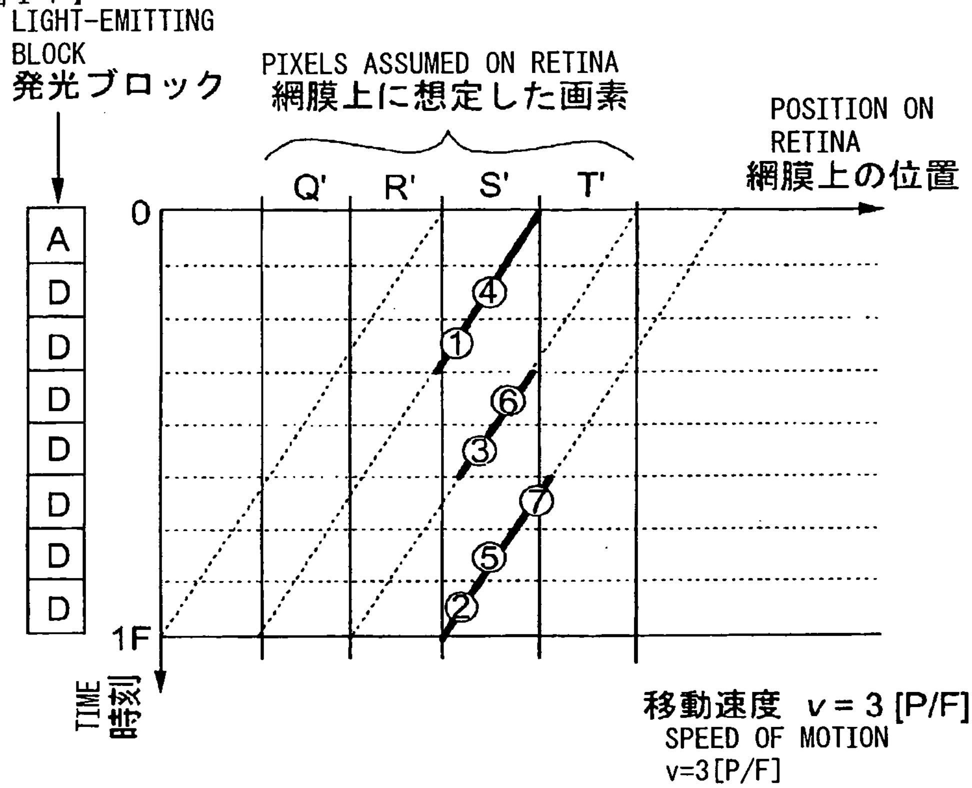
[FIG. 16]
【図１６】

整理番号:00-01273



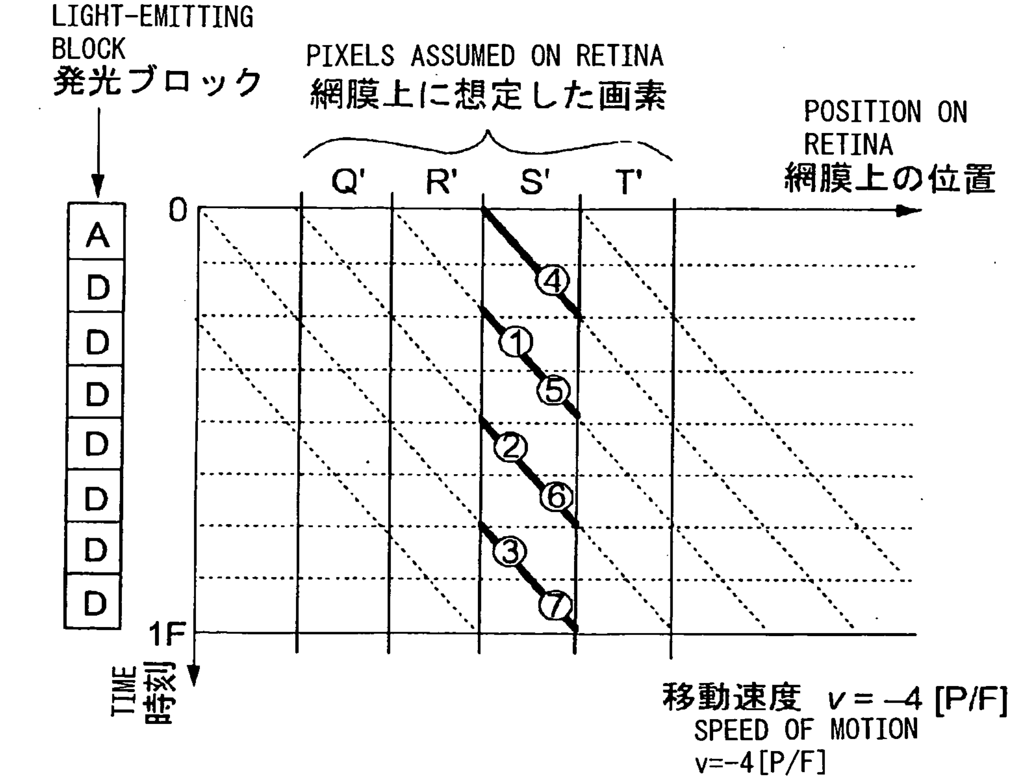
冗長発光ブロックの選択順序 (移動方向左)
THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS(MOVING DIRECTION IS RIGHT-TO-LEFT)

[FIG. 17]
【図１７】



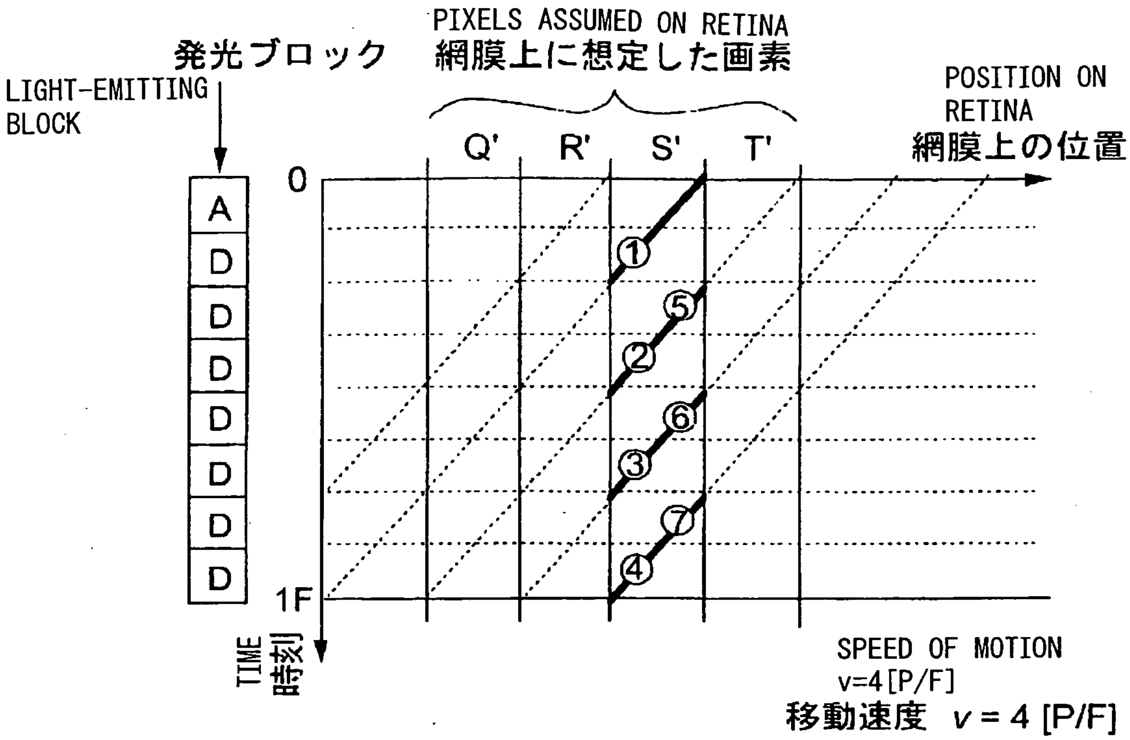
冗長発光ブロックの選択順序（移動方向右）
THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS(MOVING DIRECTION IS LEFT-TO-RIGHT)

[FIG. 18]
【図１８】



網膜上の位置が等しい冗長発光ブロックの
選択順序(移動方向左)
THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING
BLOCKS WHEN THEIR POSITIONS ON THE RETINA COINCIDE
WITH EACH OTHER(MOVING DIRECTION IS RIGHT-TO-LEFT)

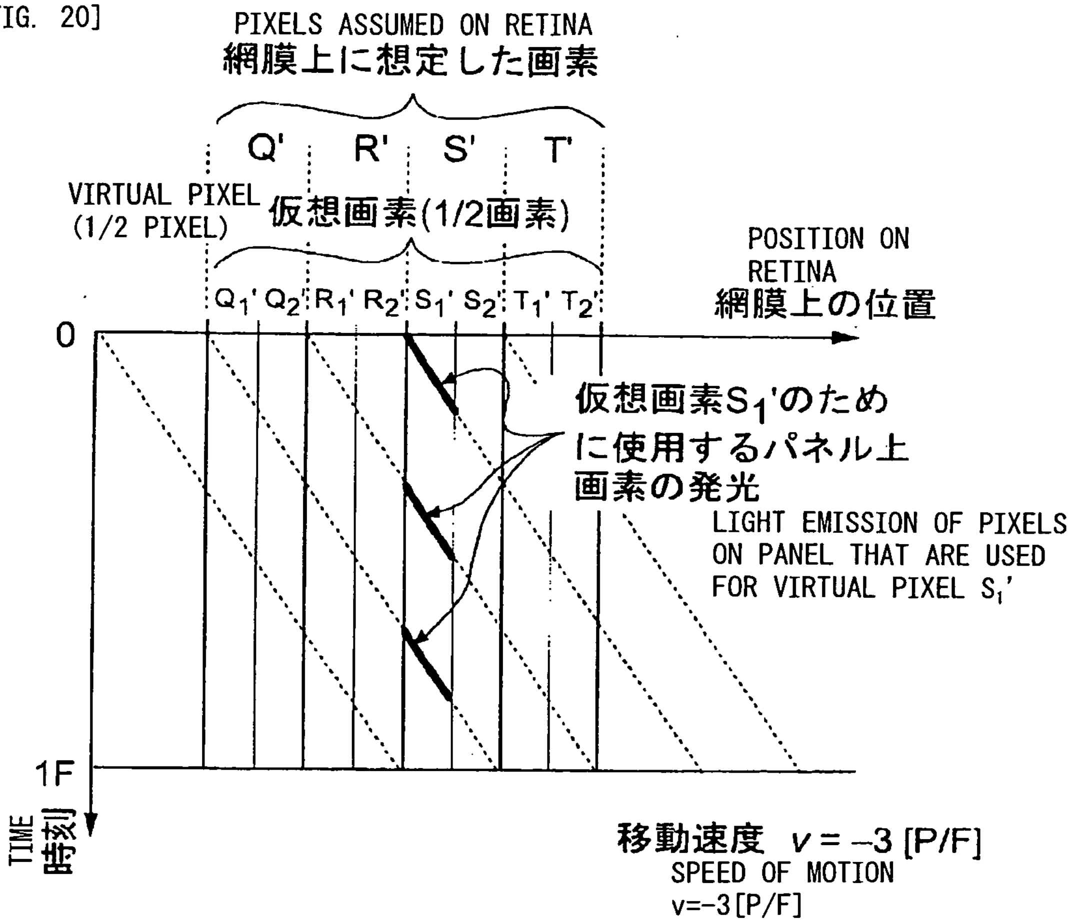
[FIG. 19]
【図１９】



網膜上の位置が等しい冗長発光ブロックの選択順序(移動方向右)

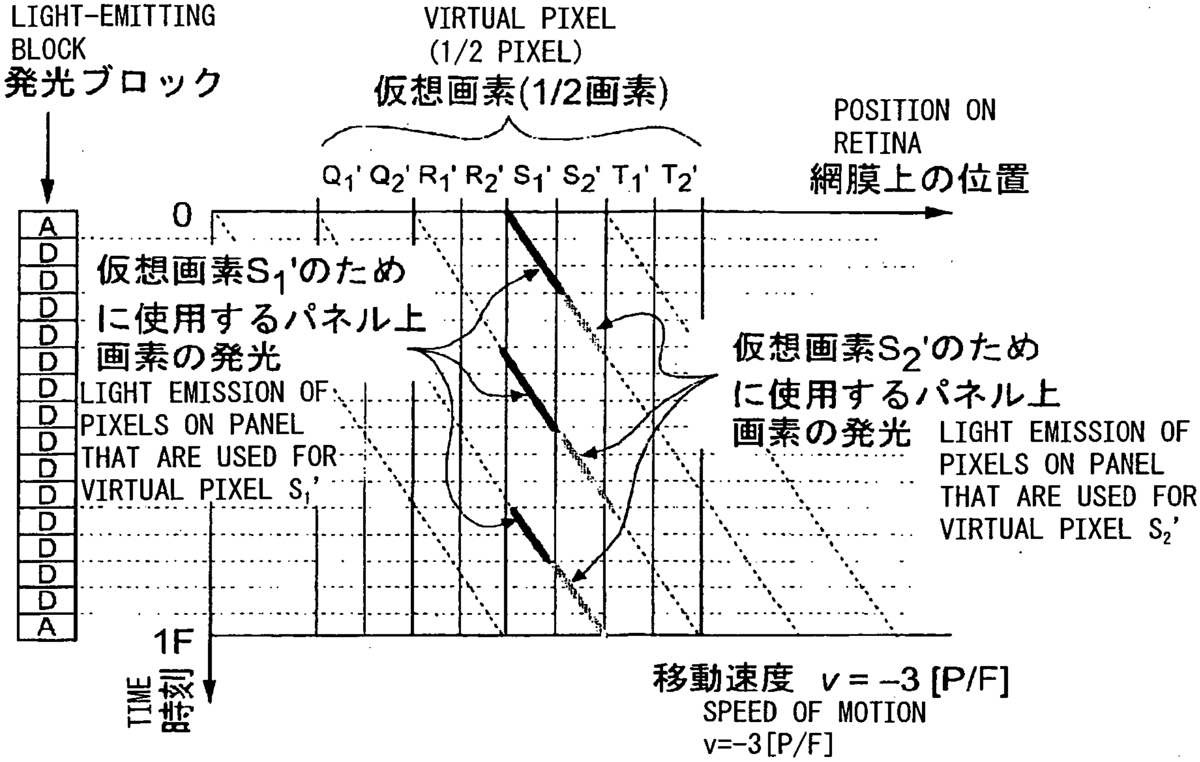
THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS WHEN THEIR POSITIONS ON THE RETINA COINCIDE WITH EACH OTHER(MOVING DIRECTION IS LEFT-TO-RIGHT)

【図２０】
[FIG. 20]



仮想画素S_1'の表現のために使用する
パネル上の画素の発光の軌跡（理想的な場合）
LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING A VIRTUAL PIXEL S_1' (IDEAL CASE)

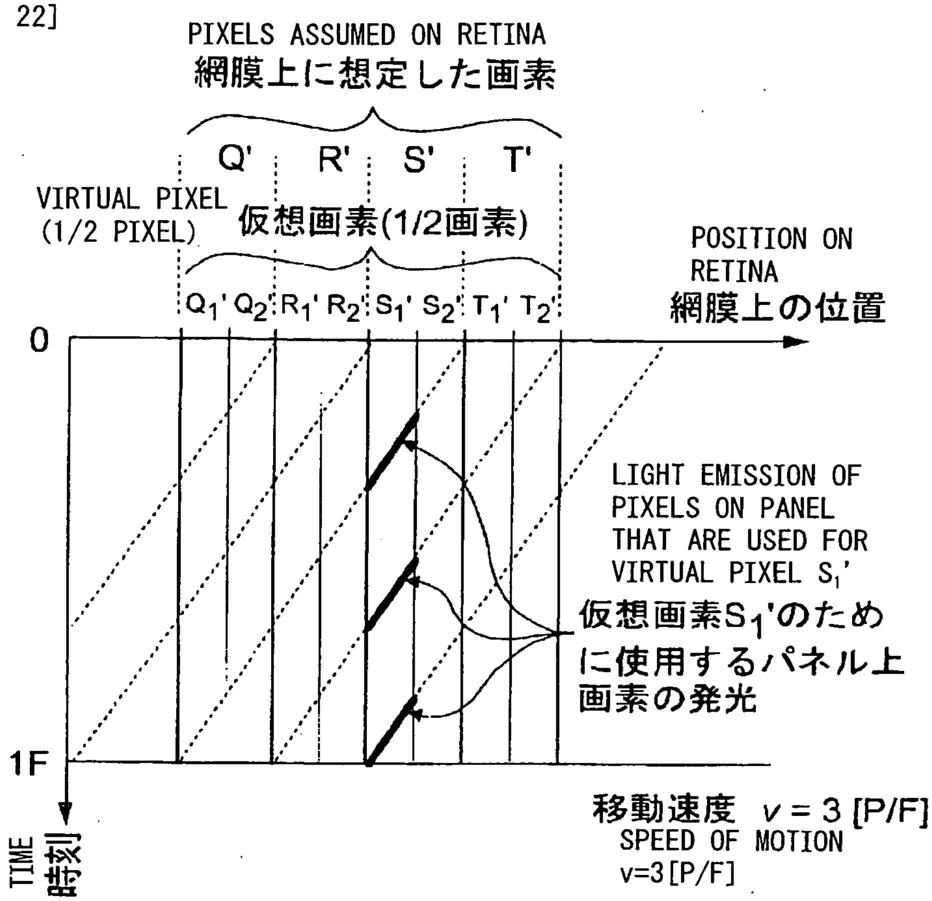
[FIG. 21]
【図２１】



仮想画素S_1'およびS_2'の表現のために使用するパネル上の画素の発光の軌跡 (発光ブロックを考慮した場合)

LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING VIRTUAL PIXELS S_1' AND S_2' (WHEN LIGHT-EMITTING BLOCKS ARE CONSIDERED)

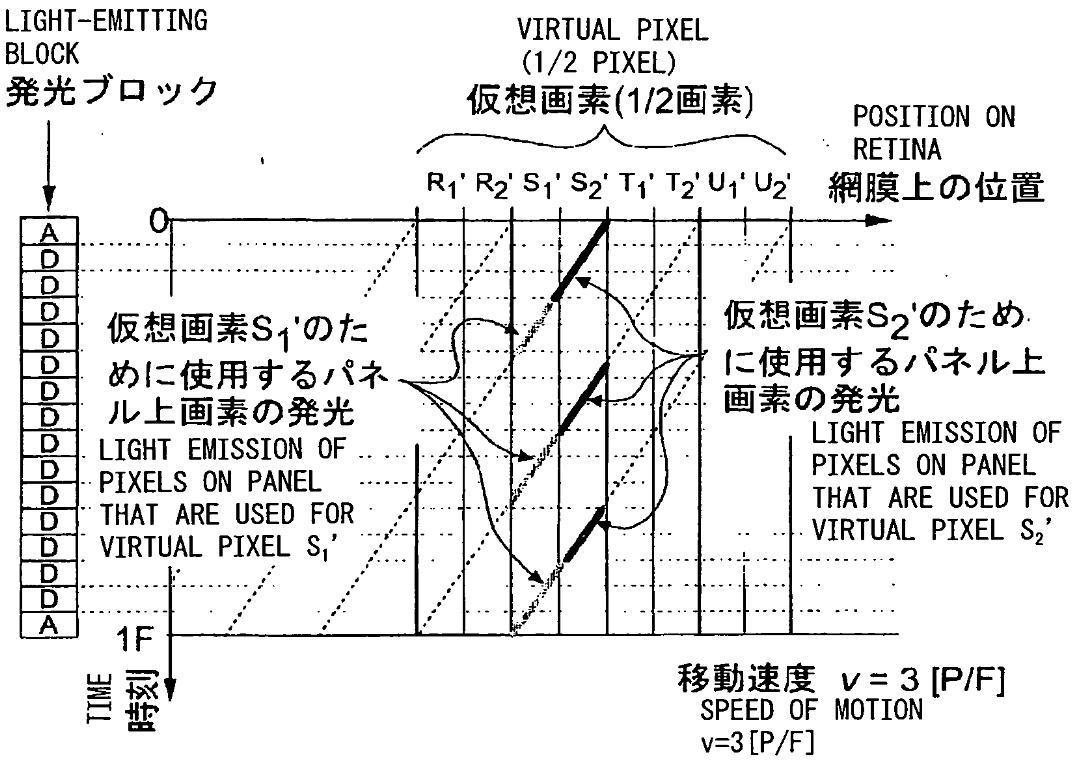
【図２２】
[FIG. 22]



仮想画素S_1'の表現のために使用するパネル上の画素の発光の軌跡 (理想的な場合)

LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING A VIRTUAL PIXEL S_1' (IDEAL CASE)

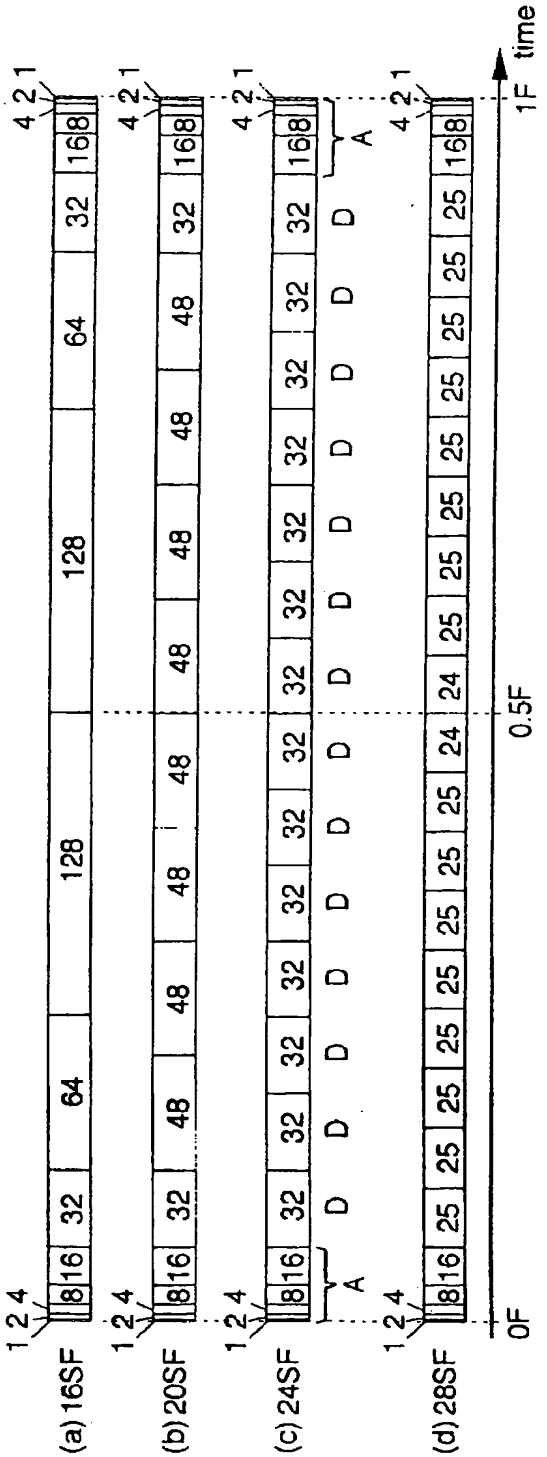
[FIG. 23]
【図２３】



仮想画素S_1'およびS_2'の表現のために使用するパネル上の画素の発光の軌跡 (発光ブロックを考慮した場合)

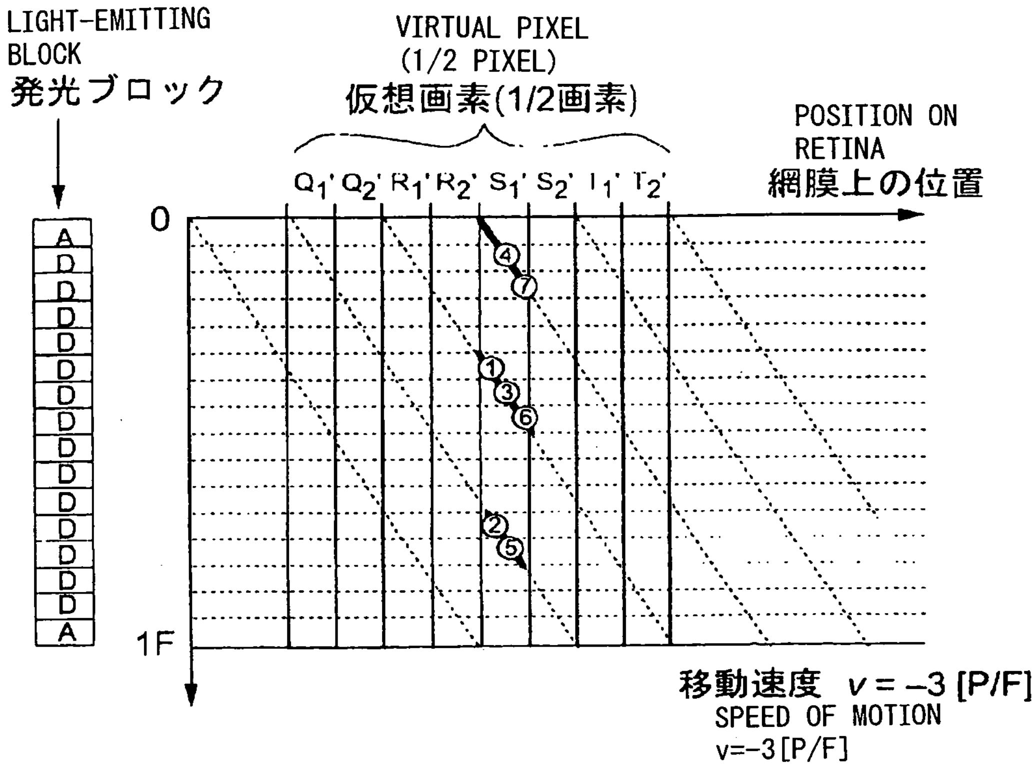
LOCI OF LIGHT EMISSIONS OF PIXELS ON THE PANEL WHICH ARE USED FOR EXPRESSING VIRTUAL PIXELS S_1' AND S_2' (WHEN LIGHT-EMITTING BLOCKS ARE CONSIDERED)

【図２４】
[FIG. 24]



仮想画素法で用いるサブフレーム配列
SUBFRAME ARRANGEMENT IN THE VIRTUAL PIXEL METHOD

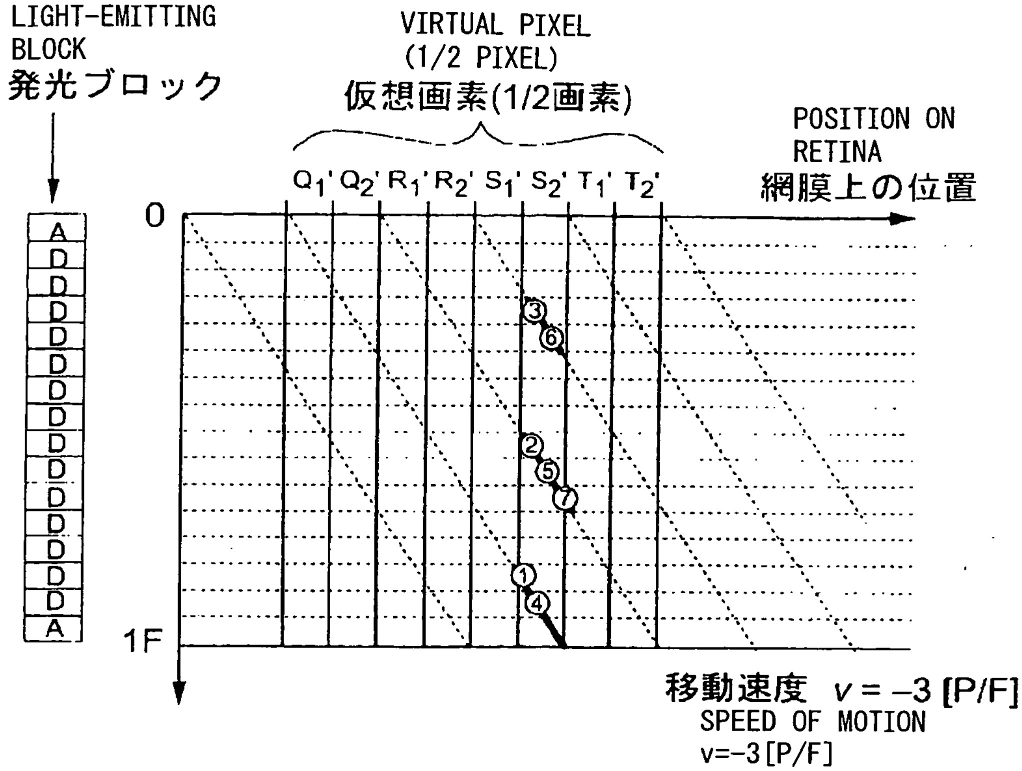
[FIG. 25]
【図２５】



仮想画素Ｓ₁'における冗長発光ブロックの選択順序（移動方向左）

THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS IN THE VIRTUAL PIXEL S_1' (MOVING DIRECTION IS RIGHT-TO-LEFT)

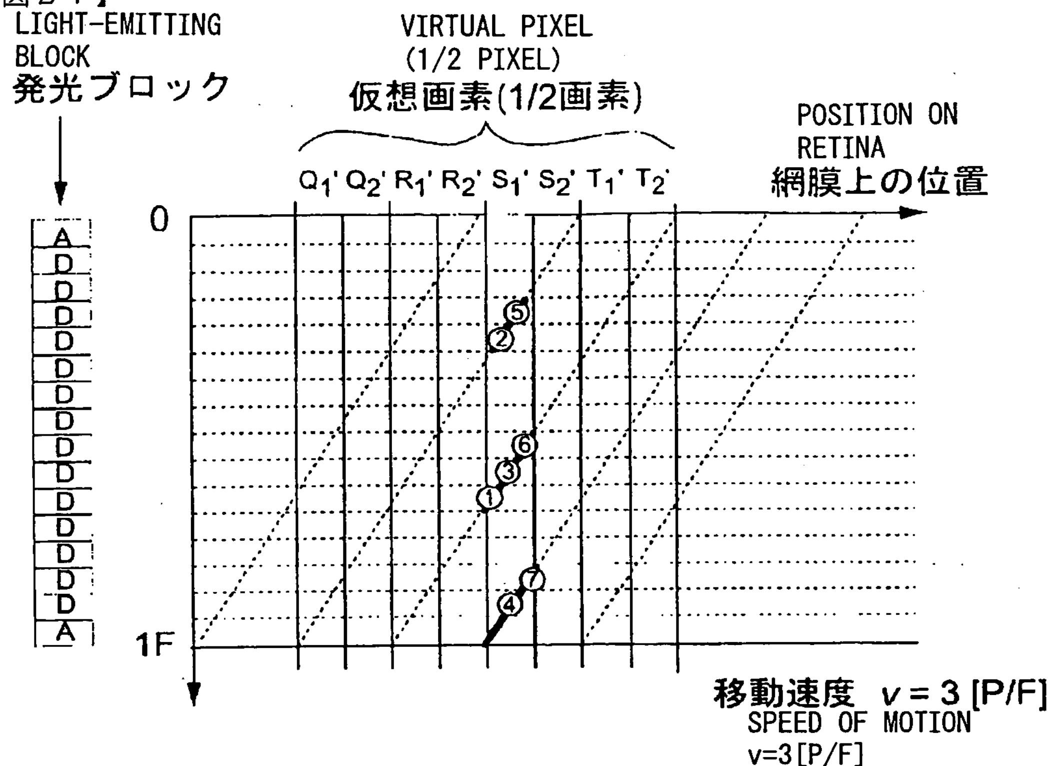
[FIG. 26]
【図２６】



仮想画素Ｓ₂'における冗長発光ブロックの選択順序（移動方向左）

THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS IN THE VIRTUAL PIXEL S_2' (MOVING DIRECTION IS RIGHT-TO-LEFT)

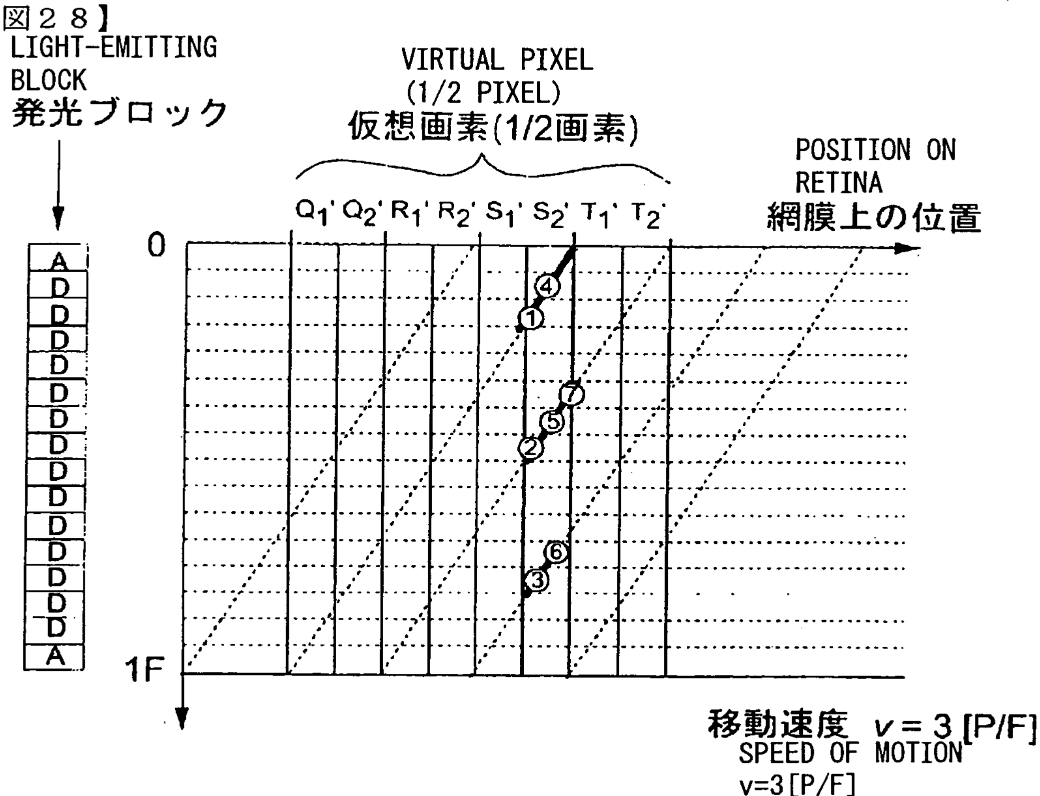
[FIG. 27]
【図２７】



仮想画素Ｓ１'における冗長発光ブロックの選択順序（移動方向右）

THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS IN THE VIRTUAL PIXEL S_1' (MOVING DIRECTION IS LEFT-TO-RIGHT)

[FIG. 28]
【図２８】



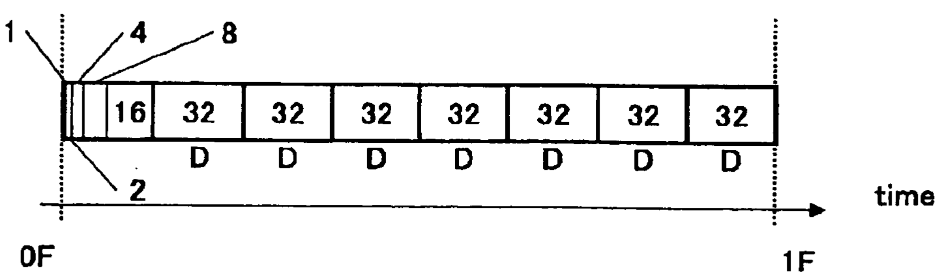
仮想画素Ｓ$_2$'における冗長発光ブロックの選択順序（移動方向右）

THE ORDER OF SELECTION OF REDUNDANT LIGHT-EMITTING BLOCKS IN THE VIRTUAL PIXEL S_2' (MOVING DIRECTION IS LEFT-TO-RIGHT)

[FIG. 29]
【図２９】

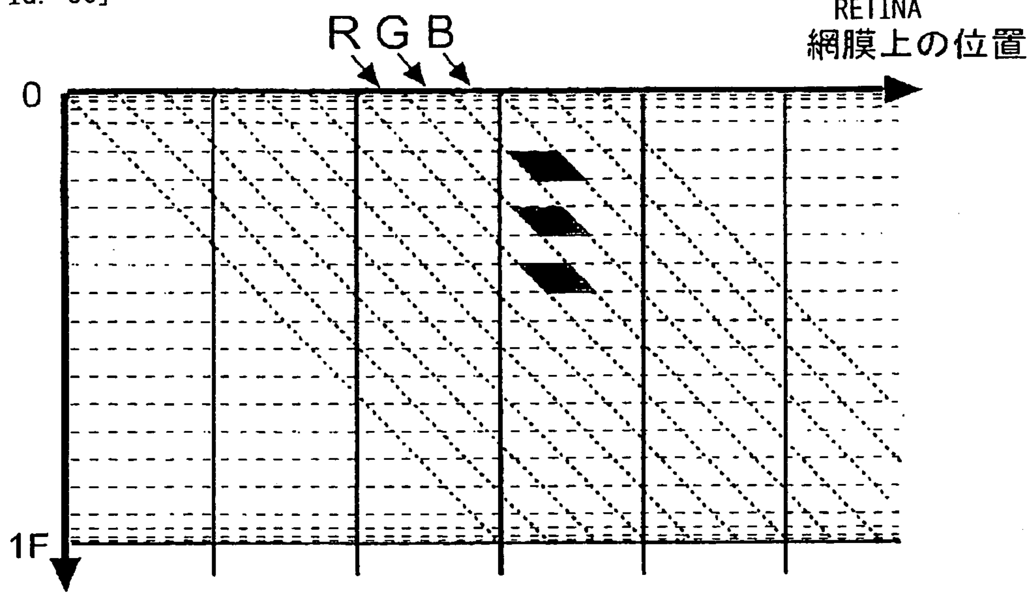
Ａ：非冗長性発光ブロック　A:NON-REDUNDANT LIGHT-EMITTING BLOCK
Ｄ：冗長性がある発光ブロック　D:REDUNDANT LIGHT-EMITTING BLOCK

※冗長性がある　＝１Ｆ内で発光期間が同じ別の発光ブロックが存在すること。
※REDUNDANT=THERE EXISTS OTHER LIGHT-EMITTING BLOCK HAVING THE SAME LIGHT EMISSION PERIOD WITHIN ONE FRAME



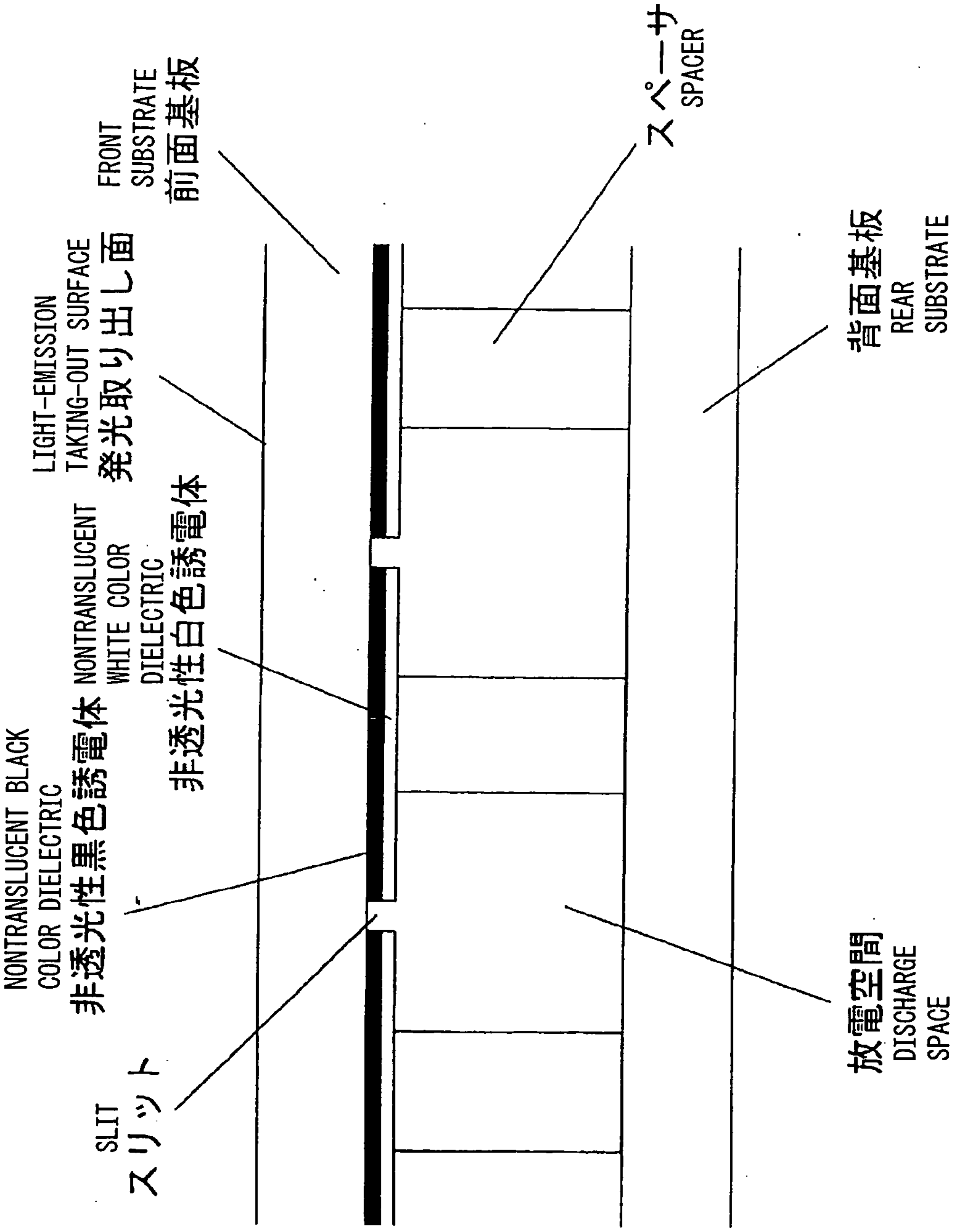
12SFのサブフレーム配列
SUBFRAME ARRANGEMENT IN 12 SF

【図３０】
[FIG. 30]



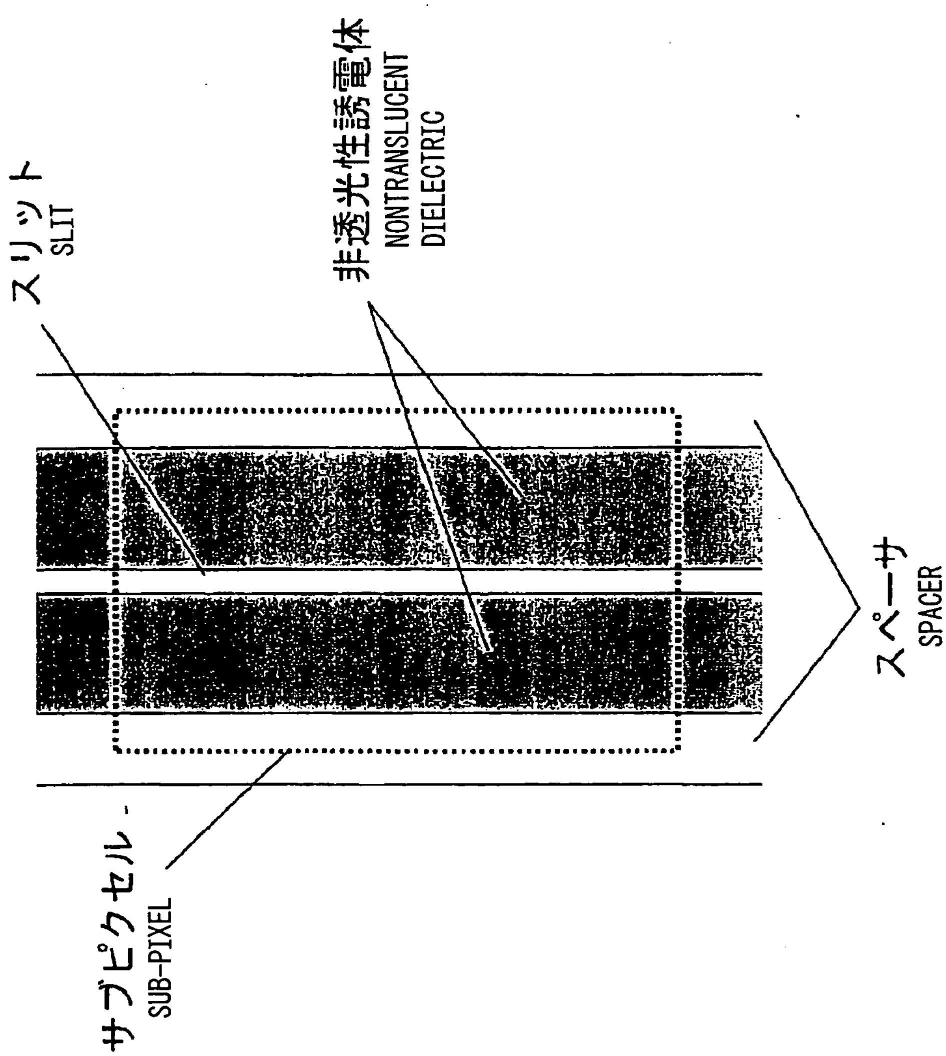
時間的に3つ並んだRGBによる白色表現
RENDITION OF WHITE COLOR USING ORDERLY
ARRANGED THREE RGB PIXELS

【図３１】
[FIG. 31]



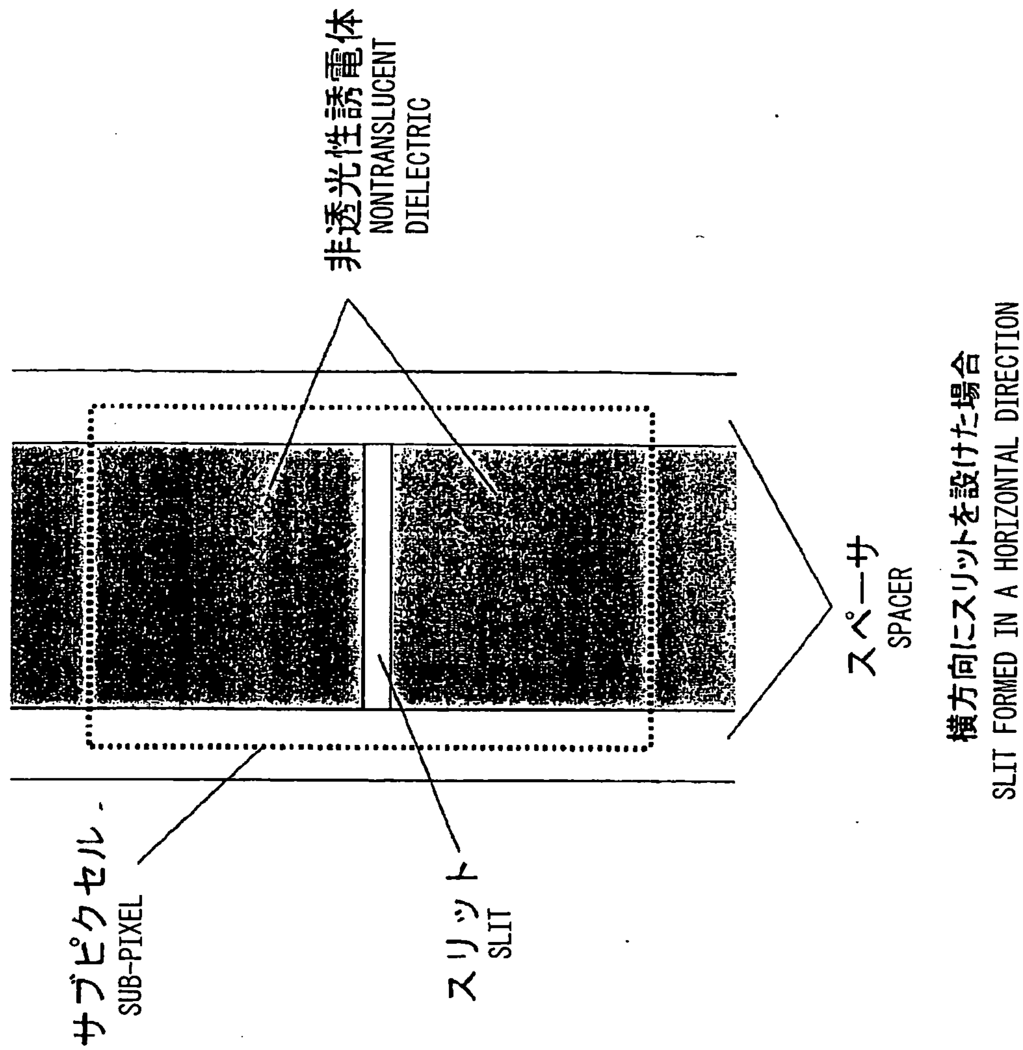
プラズマディスプレイの構造(断面図)
THE STRUCTURE OF A PLASMA DISPLAY

【図３２】
[FIG. 32]

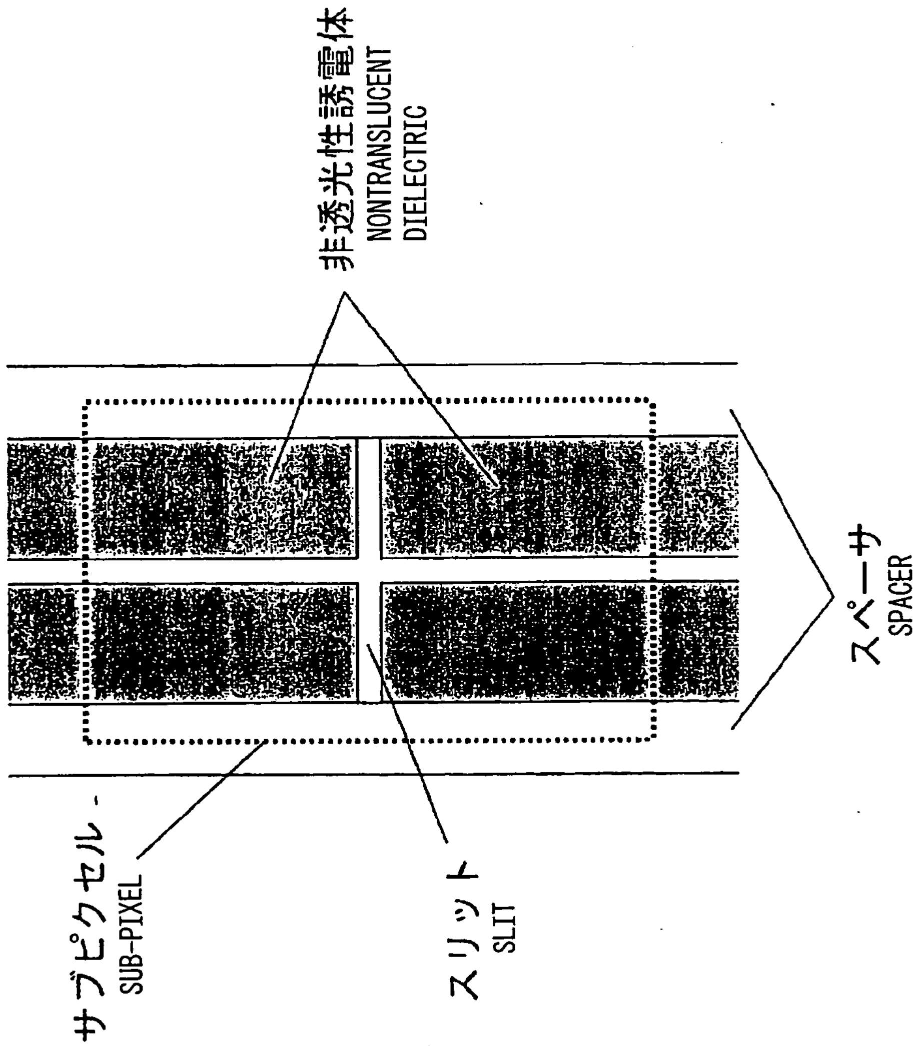


縦方向にスリットを設けた場合
SLIT FORMED IN A VERTICAL DIRECTION

【図３３】
[FIG. 33]

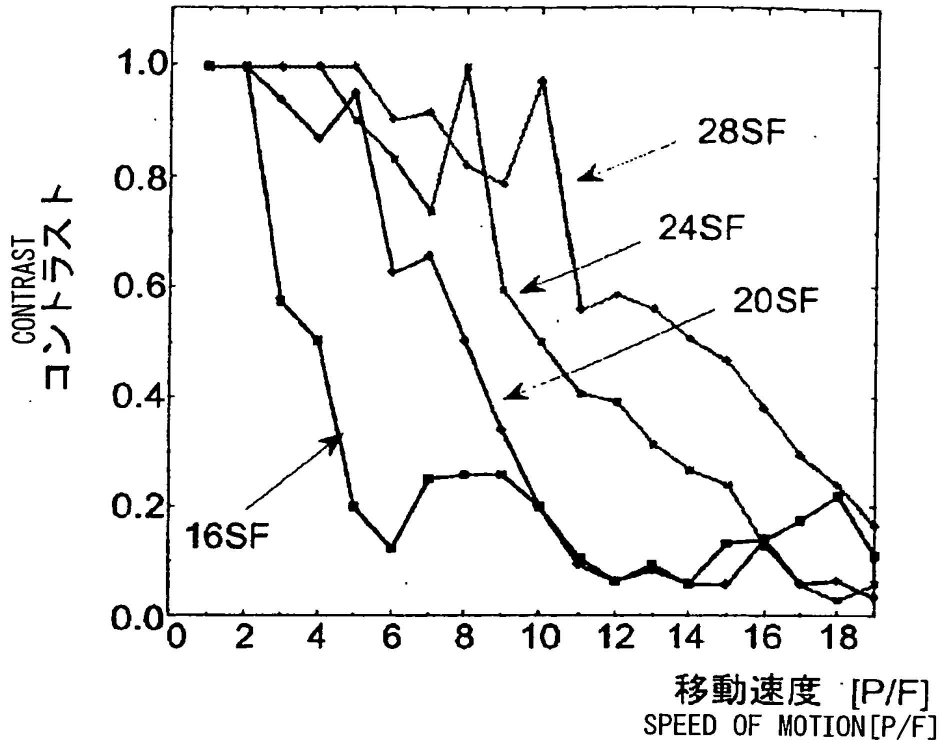

非透光性誘電体
NONTRANSLUCENT DIELECTRIC
スペーサ
SPACER
横方向にスリットを設けた場合
SLIT FORMED IN A HORIZONTAL DIRECTION
サブピクセル
SUB-PIXEL
スリット
SLIT

【図３４】
[FIG. 34]



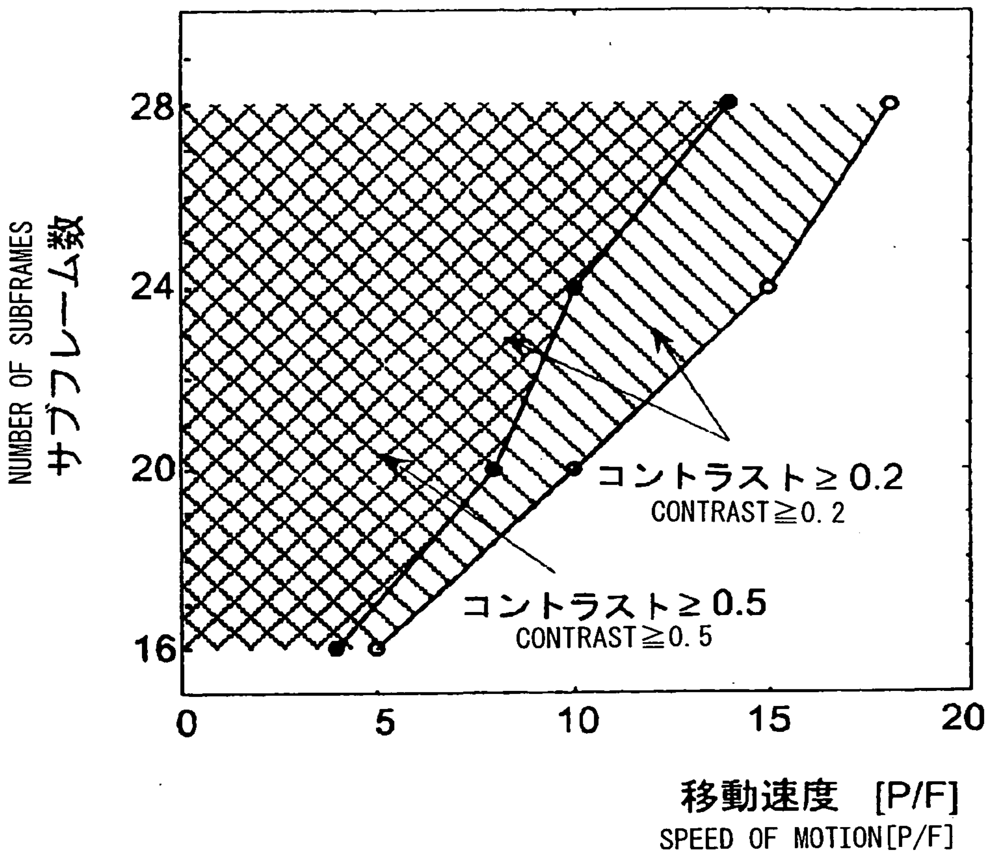
十文字型にスリットを設けた場合
SLIT FORMED IN THE SHAPE OF A CROSS

【図３５】
[FIG. 35]



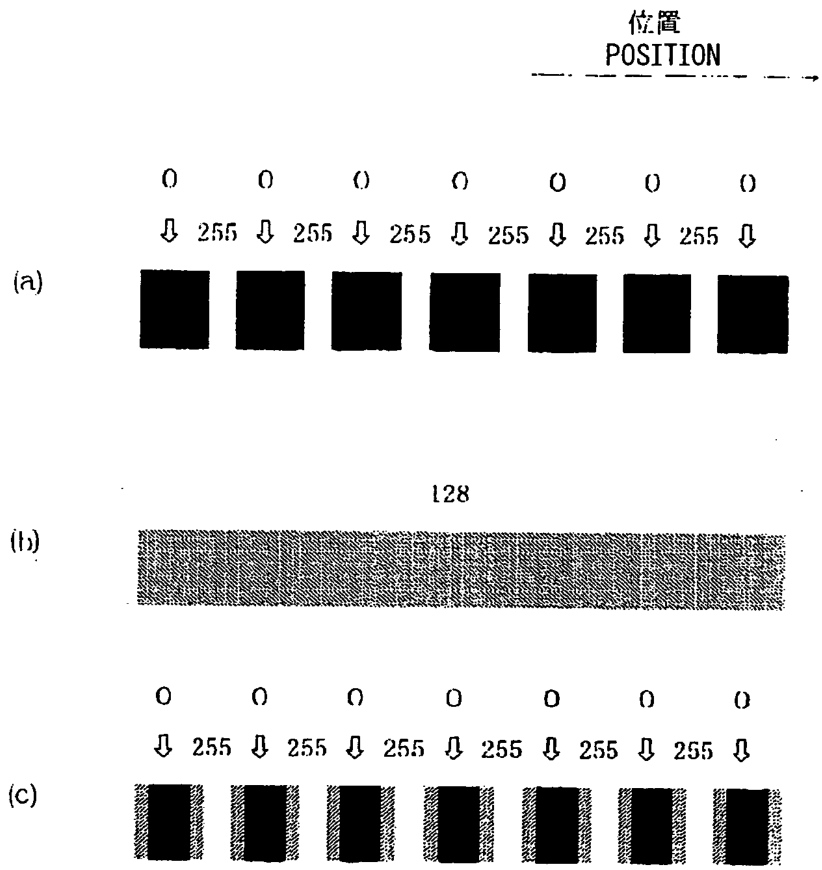
移動速度とコントラストの関係
RELATIONSHIP BETWEEN SPEED OF MOTION AND CONTRAST

【図３６】
[FIG. 36]



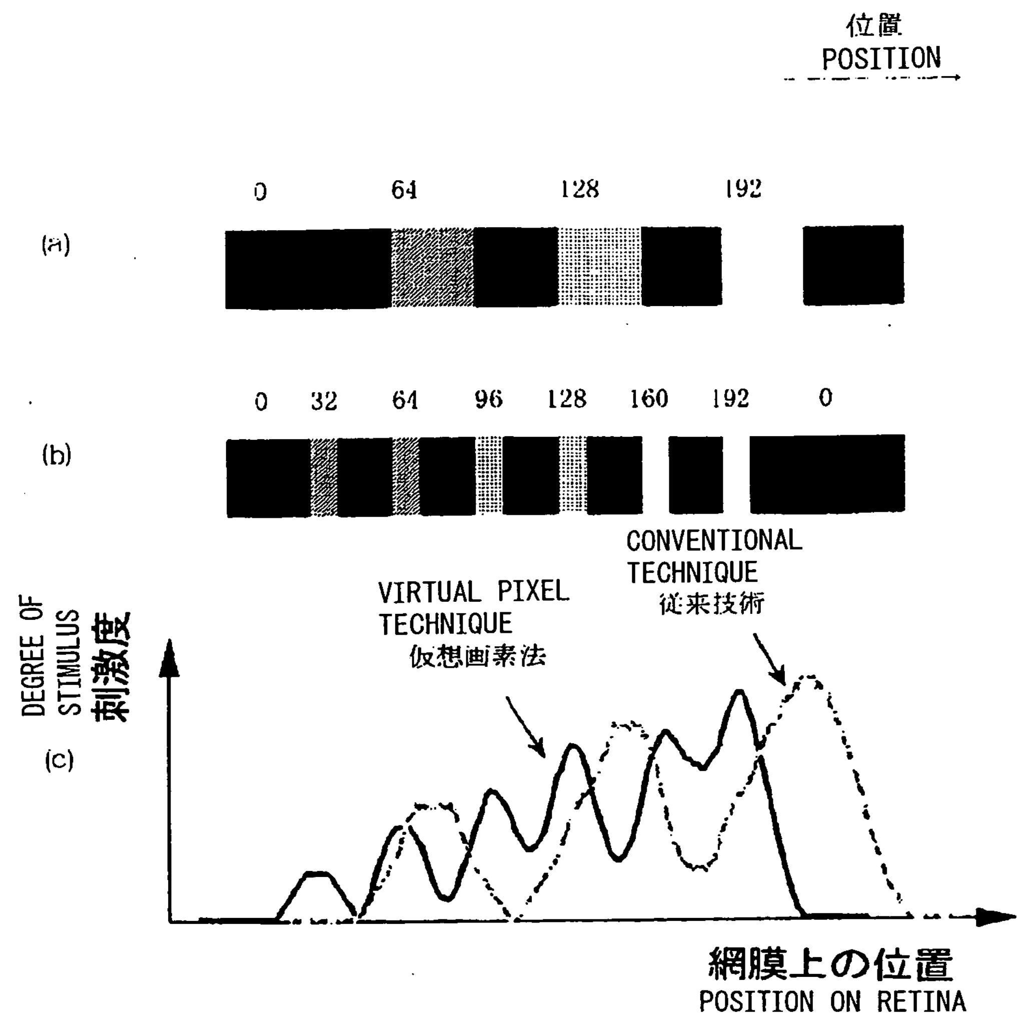
移動速度とサブフレーム数の関係
RELATIONSHIP BETWEEN SPEED OF MOTION AND THE NUMBER OF SUBFRAMES

【図３７】
[FIG. 37]



解像度の向上を示すシミュレーション結果
SIMULATION RESULT SHOWING THE IMPROVEMENT OF RESOLUTION

【図３８】
[FIG. 38]



補間法を併用した場合のシミュレーション結果
SIMULATION RESULT WHEN AN INTERPOLATION METHOD
IS ALSO USED